DOCUMENT RESUME

ED 277 833 CE 046 050

AUTHOR Shlechter, Theodore M.
TITLE An Examination of the Research Evidence for Computer-Based Instruction in Military Training. Technical Report 722.
INSTITUTION Army Research Inst. for the Behavioral and Social Sciences, Alexandria, Va.
PUB DATE Aug 86
NOTE 60p.; Prepared at the Training Research Laboratory, Army Research Institute (ARI) Field Unit, Fort Knox, KY.
PUB TYPE Reports - Research/Technical (143)

EDRS PRICE MF01/PC03 Plus Postage.
DESCRIPTORS *Academic Achievement; Adult Education; Comparative Analysis; *Computer Assisted Instruction; Computer Managed Instruction; *Costs; Educational Finance; Educational Research; *Individual Differences; *Military Training; Program Effectiveness; Program Evaluation; Research Problems; *Student Attitudes

ABSTRACT

Over 150 papers and articles were examined, and interviews with noted computer-based instruction (CBI) professionals were conducted to obtain information about CBI and the research evidence. Focus was on four main areas of CBI research--costs, learning achievements, individual differences, and student attitudes. Consistent empirical evidence did not exist to support or deny claimed advantages of CBI over other instructional media for (1) reducing training time, (2) reducing life-cycle costs, (3) facilitating students' mastery of the instructional materials, (4) accommodating individual learning, and (5) motivating students' learning. The lack of empirical support for these issues was not totally explained by problematic courseware. CBI's inherent superiority as a primary instructional medium had not been established. Most noticeable of the research problems found throughout CBI literature were confoundings due to differences in instructional content, making comparisons with inappropriate media, confoundings due to "program novelty effects," and findings that were not replicated. Recommendations were a shift in focus to identification of conditions for using computers in the instructional process and use of CBI as a supplemental instructional tool in the established instructional program. Twelve pages listing references are included. (YLB)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED277833

Technical Report 722

An Examination of the Research Evidence for Computer-Based Instruction in Military Training

Theodore M. Shlechter

ARI Field Unit at Fort Knox, Kentucky
Training Research Laboratory

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

☑ This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

U. S. Army
Research Institute for the Behavioral and Social Sciences

August 1986

Approved for public release; distribution unlimited.

CE046050

BEST COPY AVAILABLE

U. S. ARMY RESEARCH INSTITUTE
FOR THE BEHAVIORAL AND SOCIAL SCIENCES

A Field Operating Agency under the Jurisdiction of the

Deputy Chief of Staff for Personnel

EDGAR M. JOHNSON
Technical Director

WM. DARRYL HENDERSON
COL, IN
Commanding

Technical review by

Scott E. Graham
Donald M. Kristiansen

NOTICES

DISTRIBUTION: Primary distribution of this report has been made by ARI. Please address correspondence concerning distribution of reports to: U.S. Army Research Institute for the Behavioral and Social Sciences, ATTN: PERI-POT, 5001 Eisenhower Ave., Alexandria, Virginia 22333-5600.

FINAL DISPOSITION: This report may be destroyed when it is no longer needed. Please do not return it to the U.S. Army Research Institute for the Behavioral and Social Sciences.

NOTE: The findings in this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: ARI Technical Report 722
2. GOVT ACCESSION NO.:
3. RECIPIENT'S CATALOG NUMBER:

4. TITLE (and Subtitle): AN EXAMINATION OF THE RESEARCH EVIDENCE FOR COMPUTER-BASED INSTRUCTION IN MILITARY TRAINING
5. TYPE OF REPORT & PERIOD COVERED: Interim Report, June 1985-June 1986
6. PERFORMING ORG. REPORT NUMBER: --

7. AUTHOR(s): Theodore M. Shlechter
8. CONTRACT OR GRANT NUMBER(s): --

9. PERFORMING ORGANIZATION NAME AND ADDRESS: U.S. Army Research Institute for the Behavioral and Social Sciences, Fort Knox Field Unit, Steele Hall, Fort Knox, KY 40121-5620
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 2Q263743A794, 331H1

11. CONTROLLING OFFICE NAME AND ADDRESS: U.S. Army Research Institute for the Behavioral and Social Sciences, 5001 Eisenhower Avenue, Alexandria, VA 22333-5600
12. REPORT DATE: August 1986
13. NUMBER OF PAGES: 59

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): --
15. SECURITY CLASS. (of this report): Unclassified
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE: --

16. DISTRIBUTION STATEMENT (of this Report): Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report): --

18. SUPPLEMENTARY NOTES: --

19. KEY WORDS (Continue on reverse side if necessary and identify by block number):
Computer-based instruction
Computer-aided instruction
Computer-managed instruction
Evaluation
Military training

20. ABSTRACT (Continue on reverse side if necessary and identify by block number):

Consistent empirical evidence does not exist to support or deny claimed advantages of computer-based instruction (CBI) over other instructional media for (a) reducing training time; (b) reducing life-cycle costs; (c) facilitating students' mastery of the instructional materials; (d) accommodating individual learning differences; and (e) motivating students' learning. The lack of empirical support for these issues is not totally explained by problematic courseware. CBI, especially future generations of this medium (e.g.,

(Continued)

ARI Technical Report 722

20. (Continued)

intelligent computer-based instruction), promises to have a significantly positive impact on students' cognitive processing. CBI also promises to help slow learners. Problematic research procedures were found throughout the CBI literature. Most noticeable among these research problems were (a) confoundings due to the differences in instructional content; (b) making comparisons with inappropriate media; (c) confoundings due to "program novelty effects" and "teacher attitudes"; and (d) findings that were not replicated. One recommendation about future CBI research is that researchers should shift focus from examining the inherent superiority of this medium to identifying conditions for using computers in the instructional process. It is also recommended that CBI might be most useful as an instructional tool to supplement the established instructional program.

Technical Report 722

An Examination of the Research Evidence for Computer-Based Instruction in Military Training

Theodore M. Shlechter

ARI Field Unit at Fort Knox, Kentucky
Donald F. Haggard, Chief

Training Research Laboratory
Jack H. Hiller, Director

U.S. ARMY RESEARCH INSTITUTE FOR THE BEHAVIORAL AND SOCIAL SCIENCES
5001 Eisenhower Avenue, Alexandria, Virginia 22333-5600

Office, Deputy Chief of Staff for Personnel
Department of the Army

August 1986

Army Project Number
2Q263743A794

Education and Training

Approved for public release; distribution unlimited.

ARI Research Reports and Technical Reports are intended for sponsors of R&D tasks and for other research and military agencies. Any findings ready for implementation at the time of publication are presented in the last part of the Brief. Upon completion of a major phase of the task, formal recommendations for official action normally are conveyed to appropriate military agencies by briefing or Disposition Form.

FOREWORD

This report is a comprehensive examination of the research evidence regarding computer-based instruction (CBI) on costs, learning achievements, individual differences, and student attitudes. Even though CBI promises to have a significant impact upon students' learning, inconsistencies and problems with the current research evidence prohibit any conclusions about the claimed advantages of CBI over other instructional media. Recommendations are made about the methodological considerations involved in evaluating a CBI system and the usefulness of this instructional technology. A salient recommendation from this technical report is that researchers should shift focus from examining the inherent superiority of this medium to identifying the conditions for using computers in the instructional process. The conclusions are intended for military personnel and behavioral scientists interested in implementing or investigating a CBI system.

EDGAR M. JOHNSON
Technical Director

AN EXAMINATION OF THE RESEARCH EVIDENCE FOR COMPUTER-BASED INSTRUCTION IN MILITARY TRAINING

EXECUTIVE SUMMARY

Requirement:

This discussion will help the military training community understand the research literature on the usefulness of CBI as a primary instructional medium. The issues presented in this paper will also assist behavioral scientists in investigating and understanding the strengths and weaknesses of this educational medium.

Procedure:

Over 150 papers and articles were examined. Interviews with noted CBI professionals were also conducted to obtain information about CBI and the research evidence. This discussion focuses upon four main areas of CBI research--costs, learning achievements, individual differences, and student attitudes. Implications regarding future CBI use and research were also discussed.

Findings:

Consistent empirical evidence does not exist to support or deny claimed advantages of CBI over other instructional media for (a) reducing training time; (b) reducing life-cycle costs; (c) facilitating students' mastery of the instructional materials; (d) accommodating individual learning differences; and (e) motivating students' learning. The lack of empirical support for these issues is not totally explained by problematic courseware. CBI's inherent superiority as a primary instructional medium has thus not been established.

Future generations of CBI do promise to have a significantly positive impact upon students' cognitive process. This medium also promises to help slow learners. And it does not seem that CBI is a dehumanizing instructional experience.

Problematic research procedures were also found throughout the CBI literature. Most noticeable of these research problems were (a) confoundings due to differences in instructional content; (b) making comparisons with inappropriate media; (c) confoundings due to "program novelty effects"; and (d) findings that were not replicated.

Utilization of Findings:

Widespread implementation of CBI for all educational situations is not recommended. Such indiscriminate use of CBI could lead to the abandonment of this instructional technology, because the research evidence has indicated that at present the promises may outweigh the potential. CBI might be useful as an instructional tool to make the established instructional program more effective. CBI researchers must help determine those situations for which instructors can best use this medium. And the methodological recommendations discussed in this report should be incorporated in future CBI evaluations.

AN EXAMINATION OF THE RESEARCH EVIDENCE FOR COMPUTER-BASED INSTRUCTION IN MILITARY TRAINING

CONTENTS

	Page
INTRODUCTION	1
COSTS	4
Training Time	5
Operating Costs	6
Personnel Costs	9
Conclusions	10
LEARNING ACHIEVEMENTS	12
Outcome Studies	12
Methodological Criticisms	13
Transfer Studies	16
Human Factors and Effectiveness	18
Conclusions	19
CBI AND INDIVIDUAL DIFFERENCES	20
Learner Control Mechanisms	20
Cognitive Differences	21
Individual Differences and CBI Limitations	24
Conclusions	26
CBI AND STUDENT ATTITUDES	27
Attitudinal Studies	27
Psychometric Attributes of Attitudinal Measures	29
Factors Affecting Student Attitudes	30
Conclusions	33
SUMMARY AND RECOMMENDATIONS	34
Conclusions	36
FINAL IMPLICATIONS	37
REFERENCES	38

AN EXAMINATION OF THE RESEARCH EVIDENCE FOR COMPUTER-BASED INSTRUCTION IN MILITARY TRAINING*

Introduction

Computer-Based Instruction (CBI) proponents (e.g., Kearsley, Hunter, & Seidel, 1983; Myers, 1984; Shavelson et al., 1984 and Wilson, 1984) have suggested that this technology's delivery capabilities make CBI superior to other instructional modes. As Shavelson et al. stated:

> Federal and state policy makers all contend that recent technological innovations most notably the microcomputers hold particular promise not only for pulling education out of a rising tide of mediocrity, but also for reshaping education. (p1)

CBI denotes using computers in the instructional process. Computer-Assisted Instruction (CAI) and Computer-Managed Instruction (CMI) are considered to be components of CBI. In CAI, students receive instruction directly from the computer system. CMI involves using the computer for such instructional management issues as scoring, recording, and interpreting test results. Instructions for a CMI system, however, are provided off-line either by the teacher or by other instructional media. Other uses of CMI will be discussed in succeeding sections.

CBI is especially being touted as a significant instructional device for the United States' Armed Services (see Department of Defense [DoD]) Memorandum from the Assistant Secretary of Defense, 9 September 1985). Orlansky (1985) has noted that CBI is particularly applicable in training military personnel for a significant number of the over 10,000 Armed Services' skill training courses offered in such areas as electronics, maintenance, and communications. These courses will train approximately 1.4 million students at a cost of nearly 4.4 billion dollars in fiscal year 1986. The Army is planning to develop CBI programs for training different levels of troops in many different types of courses, including advanced courses for officers. One example of the Army's plans to use CBI is the approximately 420 hours of the Job Skills Education Program (JSEP), which will be put on computers (Farr, 1985). The JSEP package will involve the use of 200-300 terminals located at 19 different military sites. This program will provide remedial training for soldiers with problems mastering the skills needed in their Military Occupation Specialty (MOS). The Army's expanded plans to use CBI also involve the US Army's Armor School at Fort Knox. The Armor School is in the process of

*Portions of this report will appear as a chapter in R.T. Hartson and D. Hix (Eds), Advances in Human-Computer Interactions. Ablex Publishing Corporation: Norwood, New Jersey.

developing over 350 hours of courseware, which represent approximately 20% of the Armor School's instructional time (Major P. Carroll, DOTD, Personal Communication, 20 May 1985). Major Carroll has also claimed that the CBI courseware will be designed for different areas of armor training, including advanced and basic training courses.

A major source of support for CBI use in military training is the results of research studies which suggest advantages of CBI over conventional instruction. Several reviews of the CBI literature (e.g., Kearsley et al., 1983; Kemner-Richardson, Lamos, & West, 1984; Orlansky & String, 1981; and Orlansky, 1983; 1985) have indicated that this instructional medium has led to: (a) reduced training time and (b) reduced instructional costs. These reports have also indicated that students seemed to favor taking a course by means of CBI rather than receive conventional instruction. The CBI literature for civilian training also suggested that CBI training would be the most effective instructional mode for helping students to achieve a better mastery of the instructional content and for dealing with individual learning differences. The robustness of these findings for both civilian and military training will be analyzed in this paper.

A major weakness in the CBI literature is that very few reviews have dealt with analyzing the possible methodological problems in this research area. This paper will explore the extent to which previous research has confounded media effects with extraneous treatment effects. Avner (1978; 1979) and Clark (1985a) have noted that CBI is a medium rather than an instructional treatment and thus researchers must determine the unique educational contribution inherent in CBI as a primary instructional medium. As Avner (1979), Director of Evaluation at the Computer-Based Educational Research Laboratory at the University of Illinois (CEREL), has stated, "Computer-based education (another term for CBI) is, despite its title, more a medium for communication of information than a coherent instructional plan or approach." (p136).

Without a thorough analysis of the evidence on CBI as an instructional medium, one is ill-equipped to make recommendations and decisions about the use of CBI as a primary instructional medium for military training. Military educators must know if the courseware associated with the CBI system can be more or less effectively delivered by other instructional media. This review will then examine the state of civilian and military CBI research on costs, learning achievements, individual differences, and student attitudes. These four main areas of CBI research will be discussed in the next four sections, respectively. Methodology concerns in CBI research and implications for future CBI research will also be discussed. The civilian CBI research is discussed because decisions about using CBI in military training have been based upon this research literature.

One must also carefully examine the CBI literature because history has shown that educational innovations which were implemented without sufficient

research and planning were always abandoned for still newer educational innovations (Montague & Wulfeck, 1984). Ragsdale (1982) has suggested that the history of CBI may be following the same path as other recent educational innovations, e.g., programmed instruction, from initial enthusiasm and excitement for the innovation to its eventual abandonment. With the sizeable financial investment associated with large-scale CBI implementation, the military can ill afford to implement and then abandon this instructional medium because of poor research and planning.

Costs

A major obstacle to widespread CBI implementation is the extensive capital investment associated with acquiring a system. Reed (1983) cited an EDUCOM Bulletin (1983) report which estimated that institutions should expect to pay between $1,000 and $6,000 per student for a 1985-1990 CBI system. Hofstetter (1983) has noted that the per terminal hardware costs for a PLATO (Programmed Logic for Automatic Teaching Operations) system is $2,900. Avner (1986) has noted, however, that hardware costs are substantially lower in 1986 than in 1982 from a $128,000 yearly investment to a $33,760 investment for the terminal hardware associated with a standard 32 terminal PLATO system. However, other costs associated with the PLATO system, e.g., costs on communication systems, have doubled and tripled in the last four years. He has concluded that an institution can expect a yearly investment of $135,000-$150,000 for an entire system. These costs reflect the charges from a non-profit organization (CEREL) and for the following items: 1) thirty-two terminals; 2) power for terminals; 3) terminal site; 4) disk storage space; 5) system interface; 6) central computer; 7) system software; 8) central building; 9) service travel; 10) support personnel; 11) support equipment; 12) supplies and spare parts; and 13) communication system to host computer. Avner's figures do not reflect expenditures for courseware materials nor for instructors.

Hardware costs for MicroTICCIT (Microcomputer Network of the Time-Shared Interactive Computer- Controlled Information Television System) are approximately $250,000 for a ten terminal system. This price estimation includes a host terminal, color terminals, videodisc players, and a hefty charge for lifetime authoring privileges. These costs do not reflect expenditures for producing courseware materials nor for classroom personnel.

Christiansen (1985) observed, however, that the cost value of any product should be determined by its life cycle costs rather than by its initial outlay costs. As indicated previously, many CBI reports (e.g., Hofstetter, 1983; Kemner-Richardson et al., 1984; Orlansky, 1985; Orlansky & String, 1983; and Seidel, 1980) have suggested that such systems are cost effective (same effectiveness at reduced costs or more effective at the same cost than alternative media) and would eventually lead to savings in educational expenditures. Kemner-Richardson et al. noted, for example, that the PLATO system as compared to conventional instruction would lead to a $180,000 a year savings for an average military educational program. Such analyses of life cycle cost savings attributable to a CBI system traditionally have involved estimating operating costs and personnel costs which would accompany implementation of new programs. Life cycle cost estimates for military systems have also involved calculating the dollars saved by reducing military training time.

Training Time

A most pervasive finding in the CBI literature, especially the military literature, is that use of CBI leads to reduced training time. Orlansky noted that the median savings time for 19 military studies when compared to conventional instruction was 30 percent with a time savings range of -31 to 89 percent. These studies have also failed to find any noticeable decrements in students' learning associated with spending less time in instruction.

Dallman, Deleo, Main, and Gillman (1977) reported that such a 30% time reduction would bring about a yearly savings of $23,000 for an Army course on vehicle repair which trains approximately 375 students per year. Orlansky (1985) believed that a 30% time savings could translate to a yearly financial savings as large as $10 million in FY 1977 money for training 50,000 Navy students. Both Dallman et al's and Orlansky's cost estimates are based upon calculating students' pay and allowances for the amounts of time saved in training.

Training time savings could further reduce military expenditures by allowing more students to complete a course without the military's having to hire additional instructors. A three week savings in a ten-week course would allow the military to teach the same course a few more times each year without hiring additional staff. Dallman et al.'s (1977) and Orlansky's (1985) cost savings estimates may then be conservative.

CBI and conventional instructions, however, are not equivalent media for measuring students' training time. Avner, Moore, and Smith's (1980) argument that CBI should be compared to other self-paced individualized instructional media, e.g., programmed texts, is especially relevant for training time data. CBI and other forms of individualized instruction allow the students to proceed at their own pace, while conventional instruction does not.

Mixed results have been found when CBI has been compared to programmed texts. Time savings of approximately 50 percent for both CBI and programmed texts as compared to conventional instruction have in fact been reported when all three media have simultaneously been tested (Orlansky, 1985). Dallman et al. (1977) cited a study conducted at the Aberdeen Proving Grounds which showed a 10% savings time for CBI when directly compared to programmed texts. Other studies (e.g., Dallman et al., and Hemphill, 1986) found, however, that students took significantly longer to complete a CBI lesson than to complete an equivalent programmed text lesson. Time savings may then not be ascribable to CBI, but to self-pacing, which characterizes nearly all modern instructional innovations. Programmed texts are usually a fraction of CBI's cost for initial implementation. According to the Command and Staff Department at Fort Knox, the production costs for a 133 page programmed text are between $1.00 and $3.00 depending on whether the book is published by contract or by the military.

Another problem with the CBI literature on time savings is that CMI has been compared to conventional instruction. These time savings effects can only be attributable to differences in instructional management techniques e.g., time in scoring tests, rather than instructional attributes inherent in

CBI. Evaluators should then test the effects of CMI with other (perhaps less costly) administrative aids. Again, confounded comparisons have been made in measuring time savings associated with CBI.

A third problem with the time savings data is a lack of replicated findings. As stated by Longo (1972):

> A paramount notion underlying any research is that of replication. In question, of course, is the matter of reliability of information across time, samples, and conditions. (p38)

Without replication and information on reliability, research data have little value. Orlansky's (1985) report on the time-savings data does not include any description of studies which were replicated for similar instructional programs using the same computer system. Also inconsistent findings were reported by Orlansky when CBI, regardless of the computer system, and conventional instruction were compared for similar instructional situations. For example, time savings for electronic courses associated with CBI were found for Army personnel at the Signal Training School but not for Navy personnel at San Diego.

Operating Costs

Determining life cycle costs also includes estimating the hidden costs associated with operating a CBI system. Kopstein and Seidel (1969) have identified maintenance and courseware production costs as the major variables in estimating hidden costs.

Hofstetter (1983) noted that the maintenance costs of the PLATO system would be minimal. He estimated the hourly maintenance cost per PLATO system to be 21 cents. This figure is based upon dividing the number of terminals into the money included in the contract for maintenance costs. His calculations do not consider the system's actual reliability.

System reliability is important to measure, because repairing malfunctions will cost additional money in repairing the problem areas and in training time losses. Holmes (1982) has indicated that an unreliable system may result in severe loss of instructional time as faulty equipment may have to be shipped to outside repair centers. A system reliability index--(failures per hour X terminals affected)/(working days by terminals affected) X 100--has been developed by Francis, Welling, and Levy (1983).

Avner (1986) has developed another measure, P1 = (# interruptions + mean length of interruptions)/total time) or P1 = (1 + mean length of interruptions)/(mean time between interruptions). Avner has claimed that these P1 indexes are the most sensitive measure of system reliability because they reflect the disruptive effect of any interruption upon the instructional program. P1 can also be computed for each component of a system (e.g., videodisc failures) and the unreliability of the different components can be added to provided an overall system reliability index.

Such reliability data for a CBI system must be compared to similar data found for alternative programs (Boldovici & Scott, 1984), otherwise the data are meaningless. Evaluators should obtain information about delays in conventional instruction. Seidel (1980) suggested that such information for non-CBI programs has rarely been ascertained.

Seidel (1980) has also suggested that cost comparisons, e.g., determining a system's reliability, between prototype CBI systems and fully operational educational systems are not a fair test of CBI's potential cost value. CBI evaluations are usually conducted for a prototype or a newly implemented system, such as Francis et al.'s evaluation. Such evaluations may then not be an accurate assessment of a fully fielded system's reliability and corresponding costs. Evaluations are needed in which reliability data are collected during the initial assessment period and after a few years of operation. Information from these evaluations would help CBI professionals to more clearly understand the discrepancies found in a system's reliability between initial evaluation and actual use.

A related question to system reliability is how long a system can last. Avner's yearly projections for the PLATO system cited at the beginning of the costs section were based upon a ten-year life-span. Except for Avner's data, little is known about the average life-span for a CBI system. Accurate information about a system's potential life-span is needed to better understand the life-cycle costs associated with CBI.

Production cost differences between CBI and other instructional media have also rarely been systematically analyzed. Several CBI proponents (e.g., Avner, 1982; Burnside, 1985; and Dallman et al, 1977) suggested that long-term production costs might be cheaper for CBI than for other instructional media. Their claims have been based on the assumption that updating CBI courseware is relatively easy and inexpensive. Dallman et al. have argued, for example, that PLATO's editing features help to reduce sharply the costs involved in updating and modifying CBI lessons. According to Avner, updating PLATO lessons is a function of the quality of the original work and the volatility of the subject matter. Some PLATO lessons need few modifications after eight years of continuous use. Another reason for reduced long-term production costs is that the CBI system will allow the same instructional materials to be repeatedly presented throughout the system's lifetime, while some separate programmed texts may have to be created for each student. Very few CBI evaluations have examined the differences in actual expenses (and problems) with updating the instructional materials for CBI and for other instructional media (Orlansky, 1985).

Initial developmental costs for a CBI program might be quite expensive. Walker (1984) reported that the developmental costs for a CBI program might range between $2,000 and $100,000 per contact hour. Johnson and Plake (1980) noted that it would have cost the University of Nebraska library over $30,000 to present a one-hour program to 4,000 students. By contrast, similar text materials cost a few hundred dollars to produce (Walker, 1984). These expenditures associated with initial courseware development might then negate the previously discussed savings associated with CBI for other production costs.

An important consideration in determining cost-effectiveness is the hourly cost associated with using the instructional medium. Tremendous variation exists in the hourly cost of CBI service. Avner (1982) has noted that PLATO terminal costs can vary depending on terminal use, software use, and distance from the central computer from $1.76 per terminal to $10.94 per terminal. Okey and Majer (1976) have noted that CAI costs per student contact hour are $2.07. The $1.76 and $2.07 figures represents nearly continuous and daily use of the system while the $10.94 figure represents sporadic CBI use. None of the figures cited has included the expenditures set aside for instructors. Also, comparisons of hourly costs for using CBI have not been made with those for other media.

Himwich (1977) and Stone (1985) have detailed the financial costs involved in developing in-house courseware. Himwich noted that military courseware developers must be formally trained in computer procedures and educational practices. He also found that it took around 230 hours to complete one student contact hour of courseware. Stone's developmental team consisted of five Army Captains, civilian educational specialists, and outside consultants. These Army personnel also had to take a computer course in order to design this courseware. Himwich's project was aborted because of financial problems and Stone's team did not meet its goal of completing 100 hours of instructional time by the following year.

Several instructional specialists (e.g., Holmes, 1982; and Montague, Wulfeck, & Ellis, 1983) believe that in-house courseware can be developed rapidly and successfully. Holmes has argued that a template system would allow instructors to design CBI courseware in a relatively short space of time and with little knowledge of computer programming. Montague et al. have argued that computer-aids can help reduce the time and thus costs involved in producing in-house courseware. Cost-effectiveness of such templates and computer-aids has rarely been studied..

Avner, Smith, & Tenczar (1984) did complete a longitudinal observation of 143 independent production groups. They found that production efficiency was best predicted by : (a) having a strict deadline time; (b) using software authoring tools; (c) having subject matter expertise; and (d) having experience with media and individualized instruction methods. The use of software authoring tools, which can be difficult for the inexperienced programmer, provides the most cost-effective method of improving both production efficiency and quality. Avner et al. have suggested the use of EnBASIC to meet the needs of most courseware programmers working with the Apple II series computers and other computers compatible with this series. Other systems, e.g., MICROTICCIT, however, dictate that a special authoring language be used. Thus a successful courseware programmer might have to know several authoring languages or programs for just one type of system.

Avner (1979; 1982) also emphasized the importance of the cousreware designers' having previous experience with the medium and the authoring language. Avner (1979) noted that an inexperienced team of courseware designers (less than a year of experience) took between 165 to 610 hours to generate

one student contact hour of instruction while highly experienced designers (greater than two years of experience) took between 27 to 180 hours to generate a similiar amount of courseware. He then concluded that:

> Much of the published data (e.g., Stone's) on production costs for CBE, for example, are based on groups with only about a year of working experience with the medium. Such data may grossly overestimate production costs possible in steady-state (existing) operations by experienced design teams and underestimate start-up costs (for inexperienced designers). (p137)

Avner (1982), however, has noted that 430 hours of experience with the TUTOR (the PLATO) authoring language is needed for experienced college teachers to produce their own administrative and pedagogical structures. He also noted that $1000 is the average cost for an experienced university staff to program an hour's worth of CBI material. This $1000 figure does not represent the overhead expenditures found for courseware developed by private companies and this figure may be reduced when authoring tools and computer-aid materials are further refined. CBI production costs must be figured for both "steady-state" and "start-up" costs and must be compared with the same costs involved in developing courseware for other media, e.g., device simulators.

Personnel Costs

Personnel costs usually are determined by estimating the increases or decreases in the number of educational personnel which would accompany implementation of new programs. As previously argued, training time savings could allow the military to train more students without hiring more instructors. Assuming that the yearly expenditures for civilian and military instructors, including benefits, range between $20,000 to $30,000, then the resulting cost savings for not hiring instructors could be in the millions of dollars. Also, if CBI is indeed more effective than conventional instruction, then, ultimately, teachers may need not be the primary instructional medium. Teachers would only be necessary to tutor problematic students and monitor operations of the computer system. Again, more students could be taught by fewer instructors.

Burnside (1985) has argued that CBI can reduce the educational support staff. His argument is based upon the expectation made by computer experts (e.g., Baker, 1978) that CBI, especially CMI, can accomplish the administrative tasks usually done by the clerical staff. Dallman et al. (1977) also projected that support staff needs would require minimal expenditures. They estimated spending only $7,200 a year for support personnel's operational maintenance tasks. This figure was based upon three civilians--a GS-9, GS-7, and GS-5--spending 20% of their time on such problems. Dallman et al.'s projection may be conservative as maintenance tasks may occupy more of these people's time than anticipated. Also, neither Burnside nor Dallman et al. made any mention of the costs involved in hiring support staff to operate and update the system. Avner (1982) has noted that the total overhead for support personnel for a civilian 32-terminal PLATO system is $989 (at 1982 market prices) per terminal. This figure includes five full-time administration

positions, nine full-time maintenance positions; seven full-time operator positions; and fifteen full-time user service (proctor) positions. Burnside's and Dallman et al.'s position may then not reflect all support staff costs while Avner's data may be a gross overestimation for a military CBI implementation. Unfortunately, this author could not find any study which provided information about actual support staff expenditures for implemented CBI systems at a military training site. Nor was any study found which compared differences in support staff needs for CBI with those of other media.

Several sources (e.g., Bellinger, 1986; Shavelson et al., 1984; Walker, 1984; and Wisher & O'Harra, 1981) have indicated that CBI may not reduce personnel expenditures. Wisher and O'Hara reported that off-line instructor task elements of PREST (Performance-Related Enabling Skills Training) CBI program increased rather than decreased instructor dependence. They also failed to find any significant performance differences between PREST subjects and those who were instructed by conventional courseware. They concluded that PREST was not as cost-efficient as was the conventional system.

Bellinger (1986); Shavelson et al. (1984); and Walker (1984) have suggested that personnel costs should also include expenses associated with training teachers to be "computer-experts." Shavelson et al. observed that using a CBI system in a typical school necessitated a staff development program which trained teachers to be thoroughly knowledgeable about computers. Walker noted that experiences at the Microcomputer Institute for Educators at Stanford University demonstrated that 180 hours of study (eight hours a day for a month) was needed to train highly motivated teachers to use microcomputers properly in the classroom. One hundred eighty hours of study is not excessive for training in "computer expertise" as the ADAPT course (authoring courseware for MicroTICCIT) involves nearly three weeks of training at eight hours per day. Walker also noted that civilian schools do not have the resources to provide the needed additional inservice training for ever-changing computer systems. The Army, though, with its computer literacy program may be better able to provide its instructors with this additional training. Clearly, such hidden costs as these teacher training programs must be included in any analysis of CBI's life-cycle costs. Of course, possible hidden costs in personnel expenditures for conventional instruction must also be examined.

Conclusions

Any claims about the comparative costs of CBI and other educational media are premature. As discussed, very few studies have actually compared the cost-effectiveness of a CBI system with the cost-effectiveness for other media. Current CBI cost estimates may have also not included all costs for this medium and may have overestimated certain costs.

Claims about the cost savings associated with using a CBI system may also be premature. Training time savings may not be attributable to this medium, but to self-pacing which characterizes any individualized instructional program. Conclusions about training time reductions and CBI are problematic

because information is not readily available about the reliability of these data. Also the cost savings in personnel expenditures associated with CBI have not been demonstrated.

The following methodological concerns must then be incorporated into future cost comparisons. If training time is the important criterion measure, than CBI must be compared with other self-paced instructional systems. Information about costs must be gathered for implemented systems. Seidel (1980) has noted that reliable and meaningful cost information will only be obtained when the innovation is in a stable, operational state. All potential costs for the CBI and the alternative medium must also be identified and examined. Cost analyses must be done for each CBI implementation. As Avner (1978) stated, "Just because 20 prestigious researchers found CBE (CBI) to be cost-effective in their application does not mean it will automatically be cost-effective in yours." (p25)

Learning Achievements

As previously indicated a major assumption behind implementing CBI is this medium's positive impact upon students' learning processes. Many CBI professionals (e.g., Bangert-Drowns, Kulik & Kulik, 1985; Eberts & Brock, 1984; Fletcher & Rockway, 1986; Kearsley et al., 1983; Kulik, Kulik, & Cohen, 1980; Robinson & Kirk, 1984; and Suppes & Morningstar, 1969) have indicated that CBI has or will lead to the development of superior instructional materials. Kearsley et al, stated that, "We (CBI professionals) have ample evidence that computers can be used to make instruction more effective or efficient in a variety of ways."(p14)

Critics of CBI research (e.g., Clark, 1985a and 1985b; and Reinking, 1985) have questioned the evidence of CBI's instructional superiority. Reinking noted that comparisons between CBI and alternative media have produced inconsistent findings. These critics have also questioned the implied assumption that CBI is an inherently superior instructional medium.

An examination of the CBI training studies is thus needed to help resolve this dispute. Existent training studies have usually compared differences between CBI students and conventional instruction students with regard to test performance and course completion. This latter measure concerns the number of students completing the course. Such studies have been referred to as outcome studies (Kulik et al., 1985). Analysis is also needed of CBI's relative efficiency for facilitating transfer. Specific CBI features affecting students' learning will be discussed in this section.

Outcome Studies

Fletcher and Rockway (1986) have suggested that CBI is an efficient instructional medium for military training purposes. They cited evaluations conducted by each service demonstrating CBI's potential effectiveness. Evaluation of a CBI program for an Army Signal Training Course showed that the CBI group achieved higher test scores and less attrition than did the control group (Longo, 1972).

Orlansky (1985) and Orlansky and String (1983) have provided evidence challenging CBI's instructional effectiveness for military training. Learning achievement was found to be about the same for the CBI and conventional instruction students in 32 of the 48 military cases reviewed by Orlansky and String. Fifteen of these studies reported slightly superior learning achievement for the CBI programs while one study reported slightly poorer achievement for the CBI group.

Francis et al. (1983) provided another example of the inconsistency found in CBI results. They conducted two studies of CBI's effectiveness for training at the US Army Missile and Munitions Center and School. PLATO simulators were found to be an effective and efficient instructional medium for the TOW (missile) Field Test Site Training Course. Data analyses failed,

however, to find any differences between PLATO students' and non-PLATO students' test results for the HAWK Continuous Wave Radar Repair Training Course.

Montague (1984) and Orlansky (1985) claimed that consistent evidence has been found in the civilian training literature for CBI's effectiveness. This conclusion is based upon a series of meta-analyses (Bangert-Drowns et al., 1980; Kulik, Bangert, & Williams, 1983; and Kulik et al., 1980) showing noticeable effects for CBI upon students' test scores. Bangert-Drowns et al. found that exam scores for secondary school students in a CBI program were .4 standard deviations higher than were the scores reported for the conventional instruction students. This finding suggested that CBI was moderately more effective than were the conventional instruction programs.

Inconsistent data for CBI's effectiveness are also found in the civilian training literature. A close examination of Kulik et al.,'s (1980) data has indicated that only one-quarter of the 54 studies cited found large or medium effects for CBI upon college students' exam performance. Alderman, Appel, and Murphy's (1978) often cited evaluation of PLATO's and TICCIT's effectiveness for community college students also found inconsistent results. The TICCIT programs had a significantly positive impact upon students' math achievement. However, significantly fewer students completed the math course for the TICCIT program than completed the conventional instruction program. No significant differences were found between PLATO and conventional instruction students' test scores and completion rates. These inconsistent findings may be due to several factors such as courseware differences or problematic research practices.

Methodological Criticisms

Clark and his associates (Clark, 1983; Clark, 1985a and 1985b; Clark & Leonard, 1985; and Clark & Salomon, 1985) have suggested that the cited inconsistent findings in the CBI literature are due to problematic research practices. They have suggested that CBI has only been shown to be more effective than conventional instructional programs when confounded comparisons have been made between CBI and other media. They have also indicated that such confounded comparisons are prevalent in CBI effectiveness literature. Clark and Leonard noted that 75% of the studies which were randomly selected for their review had serious design flaws. And Clark (1985b) has noted that the most probable source of confounding in CBI research has been that different instructional treatments were employed in the computer and control conditions.

Failure to match instructional content is a common problem in the CBI literature. Alderman's (1974) plans for the evaluations of TICCIT and PLATO described methods for comparing students' achievement for dissimilar instructional materials. He has claimed that such comparisons can be made when substantial overlap exists between objectives for the different courses. Some CBI studies. e.g., Wisher and O'Hara (1981) and those cited by Fletcher and Rockway (1986) may have indeed compared similar objectives with substantially different instructional content. The CBI and conventional instruction

programs in Wisher and O'Hara's study were designed to remedy reading problems. The CBI program consisted of eleven reading modules within the Basic Skills Learning System devised by the Control Data Corporation while the conventional classroom instruction included reading materials created by Memphis State University. The similarity of the instructional content for these two reading programs was never discussed. Wisher and O'Hara's inability to find significant differences between programs might be due to differences in instructional content. Conversely, the effects for CBI reported by Alderman et al. (1978) and Fletcher and Rockway might have been attributed to presenting different content and not to any features inherent in the CBI program.

Morrison and Witmer's (1983) comparative evaluation of computer-based and print-based job aids for a military maintenance task is one of the few CBI studies which has matched instructional content. They made a special effort to make the wording and format of the two programs identical. These two programs did differ in that the computer-based program used a branching instructional format while the print-based program used a linear model. Given these differences, the positive effects found for the computer-based program might be due to either the medium or the branching sequence.

Comparing similar instructional materials also requires that identical efforts be made in designing the courseware. Clark (1984; 1985a) discussed the possible confounding in CBI research due to differences in designing the courseware for CBI and conventional instruction. The most powerful extraneous factor which CBI studies rarely control for is that a greater effort has been made to design the CBI presentation than that required for the comparative media involved (Clark, 1984). Clark does not, however, provide any evidence that instructional effort differences do exist or effect CBI research.

Evidence does exist that some CBI program development has involved considerable design efforts. As previously stated, developing CBI courseware involves considerable time and effort. Also some CBI programs (e.g., PLATO's and TICCIT's) were designed by some of the finest educational specialists. Bunderson (1981) noted that the prototype TICCIT courseware was primarily a function of the analytical theorems and artistic talents of the courseware development team at Brigham Young University with some help from the community college teachers. The Brigham Young staff did not help with the development of any of the conventional instruction courseware used in this evaluation. One would expect that efforts associated with the classroom instruction design did not approach the efforts involved in the TICCIT courseware development.

Several CBI professionals (e.g., Gray, Pliske & Psotka, 1985; Montague & Wulfeck, 1984; and Walker, 1984) challenged the assumption that considerable efforts were spent developing most current CBI courseware. In fact, Gray et al. have suggested that most current CBI courseware is underdeveloped. Walker has contended that there is a lack of quality CBI courseware. Furthermore, Stone's (1985) and Himwich's (1978) developmental teams may have spent the majority of their time on programming and not on courseware designing.

Clark's (1984 and 1985a) claims about confounding due to instructional efforts differences may not be valid, but this potential confounding must be examined in future CBI studies.

Clark and Leonard (1985) described another type of confounding associated with not matching instructional content. After reviewing 42 randomly selected civilian CBI programs, they found that CBI subjects received more instruction in completing the lessons than did the control subjects. One example provided by Clark and Leonard is a study in which CBI groups have received as much as eight minutes more of drill-and-practice time than have the conventional instruction groups. Practice effects rather than the medium may have influenced the achievement gains found for the CBI students. The extent to which such additional instructional time is a problem depends, of course, on the observed amount of instruction to the amount intended by a system's designer. And the need for instructor prompting undermines CBI's promise to reduce costs by reducing instructional personnel. Unwarranted instruction, such as additional prompting, should then be another variable measured in CBI research.

Using CBI to supplement the instructional program is another issue associated with additional instruction. Several studies (e.g., Dengler, 1983; Jelden, 1985; and Mevarech & Rich, 1985) have indicated that CBI is effective when used with a conventional instruction program. Most of these studies, however, did not include a comparative group receiving either a similar amount of conventional instruction or conventional instruction with another educational medium.

Clark (1983; 1985a) and Clark & Salomon (1985) have argued that "novelty effects" may also confound CBI research findings. They claimed that the positive instructional effects found for CBI in the previously cited meta-analyses were due to students' initial motivation and enthusiasm to learn novel courseware, rather than to any characteristics inherent in the CBI system. Clark (1985a) has shown that CBI effectiveness may be very different for long- and short-term studies. Clark noted from Kulik et al.'s (1983) data that secondary school students' achievement scores were .56 standard deviations higher for CBI groups than for conventional instruction groups when the studies lasted four weeks or less. Differences between groups' performances reduced to .30 for studies lasting five to eight weeks and to .20 for studies lasting more than eight weeks.

Kulik, Kulik, and Bangert-Drowns (1985) argued that "novelty effects" were not pervasive in CBI research. They reported that CBI raised students' achievement scores by .26 standard deviations in the typical long-term evaluation study and by .34 standard deviations in the typical short-term study. These differences in standard deviations are not statistically significant. Since short- and long-term evaluations were not defined by Kulik et al, using Kulik et al.'s data to refute the notion of "novelty effects" may then not be valid. Clark (1985a) conceded, however, that "novelty effects," were not significant detractors from the validity of CBI studies. The issue of novelty effects will be further explored in the section on student attitudes.

Duration problems may exist for military training studies. Orlansky (1985) and Orlansky and String (1983) both noted that half of all CBI military courses lasted one week or less. Some studies (e.g., Francis et al.'s, 1983) involved limited comparisons for particular course segments. Since most military training lasts for a few months, evaluation of less than a week's duration or of only a few instructional segments are not sufficient for making equivalent comparisons between CBI and other modes of instruction. These limited durations for CBI military studies may work against the possibility of finding significant differences between CBI and control groups.

Other criticisms of outcome studies include points made about the cost studies. For one thing, existent outcome studies rarely involved an implemented system. Several CBI proponents (e.g., Montague & Wulfeck, 1984 and Gray, 1986) have argued that quality CBI programs involves quality implementation. And Bunderson (1981) noted that the TICCIT courseware used in the Alderman et al. (1978) evaluation was not completely debugged. Outcome studies using prototype systems may then provide inaccurate estimates of CBI's instructional impact.

Outcome studies have also rarely been replicated and have rarely involved comparisons with other individualized instructional media. Questions then exist about the stability of these studies' results. And any effects found for CBI may then not be due to the media but rather to attributes inherent in individualized instruction.

Transfer Studies

Evaluating CBI's instructional value also involves determining whether a system is being used correctly. Avner (1978) has observed that the correct usage of the medium is more important than the fact that it works. Correct usage of any educational system involves helping students to make the necessary transfer of information to the appropriate environmental situations.

Controversy exists in the CBI literature regarding this medium's effectiveness for facilitating transfer. Many CBI proponent's (e.g., Gleason, 1981; Kern, 1985; McLaughlin, 1985; Montague, 1984; Reigeluth & Garfield, 1984; and Salomon, 1979) have suggested that CBI would help develop the learning processes needed for successful transfer. For one thing, McLaughlin has indicated that the computer is ideally suited for developing both procedural and declarative level knowledge. Procedural level knowledge is a basic understanding of the steps involved in completing a task while declarative level knowledge involves an understanding of the principles and concepts associated with that task (Clark & Vogel, 1985). According to McLaughlin, CBI courseware should then augment students' abilities to make basic procedural level transfer--e.g., following a technical manual to troubleshoot an armor system. CBI would also help students with cognitive transfer--e.g., understanding the principles behind the repair.

CBI proponents also believe that this medium would help students to develop the memory skills needed for long-term transfer. One reason for this belief is that drill-and-practice programs would enable students to rehearse the information continuously. Continuous rehearsal is a primary way of stor-

ing information into memory (Landhauer, 1982). Also, many computer professionals and behavioral scientists (e.g., Bunderson, 1981; Kosslyn, 1981; Merrill et al., 1980; Olson & Bruner, 1974; and Salomon & Gardner, 1986) have suggested that active learning and dual-modality processing are associated with computer instruction. Active learning and dual-modality processing can help facilitate deep cognitive processing of information. And information processed into deep cognitive levels is resistant to forgetting (Craik & Lockhart, 1972). These elements of drill-and-practice, active learning, and dual-modality processing often found in CBI programs would then seem to facilitate a more permanent transfer of information than would be offered by other instructional media.

Clark and his associates (Clark & Salomon, 1985 and Clark & Voogel, 1985) challenged the assumption that CBI would augment students' transfer abilities. Clark and Voogel have suggested that current CBI courseware is geared toward helping students to make procedural level transfer but not cognitive-level transfer. Bialo and Erickson (1984), after evaluating the courseware for 163 microcomputer programs, found that 70% of the courseware dealt solely with procedural level objectives. Clark and associates correspondingly have indicated that CBI has minimal influence upon students' long-term transfer and memory process. Cognitive effects cited to be associated with CBI, e.g., deeper processing of information, are not necessarily unique to this medium (Clark & Salomon).

Limited research evidence has been collected about CBI's potential effectiveness for facilitating either cognitive processes or transfer. Gleason (1981); McDonald and Crawford (1983); and Tatsuoka and Misselt (1978) have suggested that retention following CBI training is substantial. As stated by Gleason: "Retention following CAI is at least as good if not superior to retention following conventional instruction." (p16) Nevertheless, Gleason does not provide any data to verify this claim. Furthermore, McDonald and Crawford failed to compare the retention obtained by CBI's subjects with a control group's retention performance, and Tatsuoka and Misselt's findings seem to be an artifact of the lesson's being inadvertently repeated because of hardware problems.

Several other reports (e.g., Swezey, Criswell, Huggins, Hays, & Allen, in press; Swezey, Huggins, & Perez, in press; and Pagliaro, 1983) failed to find any significant effects for CBI upon either subjects' transfer or retention performance. Pagliaro found that pharmacology students' retention performance was the same for both CBI and conventional instruction training. Swezey, Criswell et al. found that practice on a 3-D module component was more instrumental than was the instructional media (CAI, CRT or videotape) in facilitating military students' transfer on a simple engine repair procedural task. The same results were replicated by Swezey, Huggins, and Perez for a complex procedural task. CBI's potential for facilitating retention of procedural tasks must be further examined because military CBI programs are frequently used for such tasks.

Personal experience has indicated that incidental learning is an important part of conventional instruction. Students, for instance, in an educational psychology class may incidentally learn from the teacher's mannerisms

and class discussions teaching techniques which may last a lifetime. Incidental learning is another aspect of transfer which has rarely been examined. Such incidental learning may indeed not be possible with CBI because of programming limitations. In this case the spontaneity and richness found in classroom environments may not be completely duplicated. Limitations in this medium may then be limiting the courseware and not the courseware limiting the medium as previously indicated. However, some important incidental learning may be occurring in CBI which evaluators are not measuring. For instance, a CBI military training course on maintenance may also help the students to become better readers. Even though measuring incidental learning is difficult, information is needed about CBI's impact upon such learning. As noted by Reeves and Lent (1982), "The sponsors and consumers of CBI should be informed as much as possible about the ultimate effects of this medium when they make decisions about continuance, expansion, or selection." (p13)

Human Factors and Effectiveness

Sawyer (1985) noted the importance for examining human factors issues in CBI evaluations. According to Sawyer, evaluating human factors issues involves examining the effects of a system's hardware and documentation upon students' performance.

Kearsley et al. (1983) have claimed that a CBI system's response time and downtime are important factors in the success of a CBI project. These dimensions may affect user's mastery of the instructional information. Tatsuoka and Misselt (1978) noted that mechanical failures with the PLATO system had negatively effected US Air Force students' learning efficiency. Educational experts not in the CBI field have stressed the importance of measuring the relationship between educational productivity and a medium's downtime. Gump (1985) suggested, for example, that a downtime of 10% in a conventional instruction program could equal an instructional efficiency loss of 10%. Comparisons between CBI and other instructional media should examine potential instructional loss due to "downtime" problems.

The civilian computer literature (e.g., Chapanis, 1985; Card, English, & Burr, 1978; Phillips et al., 1984; and Reigeluth & Garfield, 1984) has discussed the impact that certain computer hardware features have upon users' performance. Card et al. found significant differences in subjects' abilities to use four common computer responding mechanisms--a mouse, a joystick, step keys, and text keys--with the mouse showing in the best results (see Card et al. for a description of these devices). Chapanis noted that people were normally able to read materials presented on a hard-copy 30% more efficiently than when they were presented on a CRT. Phillips et al. reported that problems with screen visibility on CRT's impeded the educational performance of secondary school students. They also found that awkwardly designed keyboards and terminals poorly placed in classrooms led to educational problems.

Documentation problems may also adversely affect CBI's education potential. One cannot fully understand nor use any instructional procedures without adequate source materials. Bialo and Erickson (1984) found the documentation to be barely adequate for most of the 163 microcomputer systems

reviewed and information about instructional materials was absent or inadequate for 62% of these programs. Chapanis (1965; 1985) also found documentation materials for computers to be inadequate. He has shown that reading a system's documentation requires the reader to be familiar not only with normal computer jargon but also the particular system's jargon.

Conclusions

Inconsistent findings have been obtained about CBI's potential impact upon students' learning, and positive instructional effects found for CBI might be traceable to factors other than the medium. Most pronounced among these non-medium effects were practice differences and instructional content differences between CBI treatment and that of the comparative medium. Assumptions about computers making instruction more effective have thus not been validated. Human factors and courseware problems, however, may limit the computer's potential effectiveness, especially for facilitating cognitive skills. A basic unresolved question in CBI research is whether possible problems with CBI are due to such courseware and human factors limitations or due to the limitations of the medium.

CBI researchers need to obtain more conclusive data on the long-term effects of CBI. A primary function of any educational program is to insure that long-term changes occur within the students. The military is especially interested in troops retaining skills and knowledge for an indefinite period of time.

Handling individual learning differences has long been a difficult problem for educators. Many CBI professionals (e.g., Avner, et al., 1980; Carrier, 1979; Kearsley et al., 1983; Merrill et al., 1980; and Steinberg, 1984) believe that this medium is ideally suited to handle individual learning differences. As stated by Carrier, "To many educators, the computer represents the ultimate individual difference machine."(p25)

CBI's superiority over other media would then be most pronounced for meeting the educational needs of all students. Arguments supporting this position have come from CBI reports on learner control mechanisms and cognitive differences. Reports by Carroll (1984); Hess & Miura (1985); and Wood & Pitz (1985) have suggested, however, that some students may have problems learning from a CBI program.

Learner Control Mechanisms

A basic belief held by many educators is that students should be encouraged to make educational choices for themselves (Carrier, Davidson, Higgson, & Williams, 1984). Such choices would enable students to more actively process the instructional material. As previously indicated, such active learning would lead to superior learning. Learner control is also expected to help educators deal with individual learning differences. Gay (1985) has noted that:

> It is commonly assumed that individual differences in abilities and aptitudes will be accommodated if learners have more control over the pace, amount of practice, or style of instructions they receive.(p1)

CBI designers have developed learner control mechanisms which provide students with some degree of freedom in selecting the instructional materials to study. TICCIT students, for example, can select, through a special keyboard, the display best suited for their educational needs (Merrill et al, 1980). Merrill et al. have also claimed that this learner control mechanism differentiates TICCIT from other instructional media, including PLATO and some other CBI systems.

Some research evidence (e.g., Collier, Poynor, O'Neill, & Judd, 1973; Fishman, 1985; and Hansen, 1972) exists supporting the use of learner control mechanisms over program control (computer controlled sequences). Hansen found that learner control subjects exhibited greater decreases in state anxiety than did control subjects. Collier et al. also found reduced anxiety levels to be associated with using learner control mechanisms. Increased learning usually occurs when anxiety toward the instructional material is reduced. Fishman observed that learner control mechanisms allowed students to have the additional practice needed to most effectively master the material. She found that learner control students outperformed students who

received instruction from lecture and video presentations. Perhaps then, learner control mechanisms can make CBI a unique and superior instructional medium.

Several reports (e.g., Ford, Slough, & Hurlock, 1972; Gay, 1985; Judd, Daubek, & O'Neil, 1975; Snow, 1980; Steinberg, 1977; and Tennyson & Buttrey, 1980), however, have challenged the previously cited research about the instructional effectiveness of learner control features. Steinberg in a comprehensive review of this literature concluded that students who were given complete control over course flow took longer to complete the course than did control students. Also, experimental and control students scored equally well on achievement tests. Ford et al. did not find any improvements in Navy students' learning in the Basic Electricity and Electronics School associated with using learner control mechanisms. Tennyson & Buttrey noted that when students controlled the instructional process, they often terminated the process too early and did not effectively learn the materials. Judd et al. furthermore, concluded that a complex interaction existed between subjects' ability to use learner control mechanisms and the subjects' characteristics. Students with high Achievement-Independence scores--as measured by the California Psychological Inventory--were the students most able to use the learner control features.

Gay (1985) found that learner control mechanisms did not accommodate individual background differences. Subjects with high prior conceptual understanding of the material made significantly better use of these control options than did subjects with poor prior understanding. Reinking (1983) and Carrier et al. (1984) also found that control options did not accommodate individual learning differences. Reinking found that the use of learner control options did not improve poor readers' level of reading. All students may then not be able to use and benefit from learner control options.

Cognitive Differences

If CBI's instructional impact was not found for the learner control issue, it might then be discovered by examining the cognitive differences literature. Many reports (Allen & Merrill, 1985; Bangert-Drowns et al., 1985; Farr, 1985; Gray et al., 1985; Neimiec & Walberg, 1985; and Zemke, 1984) have suggested that the main reason for selecting a CBI system is to better deal with differences in cognitive abilities and styles.

Most studies concerning disadvantaged learners have used highly structured drill-and-practice programs (see such projects as the Cleveland Public Schools, 1981 and Mevarech & Rich, 1985). Such courseware seemed to provide poorer learners with the needed additional structure of and practice with the materials. As Bangert-Drowns et al. discovered, CBI had the most effect upon increasing low ability students' test scores than for any other usage. The meta-analysis comparison between CBI and conventional instruction revealed an effect size of .46 in favor of CBI for teaching low ability subjects. Zemke (1984) also observed that low achievers seemed to gain a great deal from CBI.

Problems do exist with selecting a CBI program based on this literature. Mevarech & Rich (1985), Reiss, Bass, and Sharpe (1986); and Zemke (1984) noted that CBI programs were the most effective when used to supplement the classroom instruction. As stated in the previous section, many of these supplemental studies did not include a comparative control group. Improvements in disadvantaged students' learning could have then been produced by using any instructional medium to supplement the conventional instruction program.

Drill-and-practice programs might not be useful for all subjects. Such courseware might be too structured and limited for most students, especially gifted students. B. Clark (1983) has concluded that gifted students need tasks which allow them the freedom to proceed beyond a rudimentary rehashing of the materials. Since drill-and-practice programs dominate the market, most current CBI programs may have limited value for gifted students.

Data from a study conducted by Barsam & Simutis (1984) provided some insight into courseware which might be geared toward certain kinds of gifted students. This study explored the relationships between individual differences in spatial abilities and soldiers' performance on a CBI terrain visualization task consisting of three-dimensional graphics. This study also examined differences in soldiers' abilities to benefit from courseware which utilized either active (subjects select the graphic for viewing) vs. passive (computer selects the graphic for the subjects' viewing) training procedures. They found that the high spatial ability subjects were better able to complete the lesson successfully and benefit from the active training procedures than were soldiers with normal and low spatial abilities.

The high-spatial ability students seemed to have learner characteristics similar to "field-independent" students (Witkin, Goodenough, & Karp, 1967), who are usually the high achievers in math and science courses. (See Witkin, Moore, Goodenough, & Cox, 1977 for a further description of the relationship between field-independence and math/science aptitudes). Field-independent students are also quite analytical in viewing three-dimensional objects and can also benefit from self-structuring the instructional environment. Correspondingly, then, students with mathematical and scientific aptitudes would be the most likely to successfully handle CBI lessons, e.g., simulation programs with numerous complex graphics. These last few paragraphs suggest that: (a) the basic drill-and-practice CBI programs favor the poorer learners while (b) the advanced CBI simulation courseware is geared toward the more "gifted students," especially in mathematics and science.

Variability in students' abilities to use different types of CBI programs should then relate to cognitive style differences. Witkin et al. (1977) claimed that individual differences along the field independence/dependence continuum reflected basic differences in people's characteristic styles of dealing with the environment. This continuum does not differentiate students with different I.Q. levels. It does differentiate students with different modes of handling instructional materials. Field-dependent people rely on external sources, e.g., teachers, to structure and help understand the complex perceptual and abstract stimuli, e.g., computer graphics, while field-independent people do not need such external aids. And, as previously indicated, field-independent people are better able to more effectively use the

information inherent in such situations. Witkin et al. have also observed that instructional situations with explicit instructions, concrete presentation of stimuli, and explicit information about performance outcomes favor field-dependent students. Field-independent students are better able to perform on more abstract and less structured tasks. One would then expect that drill-and-practice CBI systems with structured instructional sequencing and continuous performance feedback would be the most appropriate for field-dependent people. CBI programs with complex graphics and learner control features--as described in the previous paragraphs--would be more geared toward field-independent people.

Limited and contradictory evidence exists about the actual relationship between current CBI programs and cognitive styles. Carrier et al. (1984) and Park and Roberts (1985) found data which indicated differences--as expected--in CBI performance associated with cognitive style differences. Park and Roberts found that field-dependent people did need more guided instruction to complete a set of CBI lessons than did field-independent people. Carrier et al, however, did not find differences between field-independent and field-dependent subjects in their use of control options. Burger (1985) did not find any significant relationships between students' cognitive styles and CBI preference and performance.

An instructional system's adaptability to a students' cognitive style is a major issue addressed by Witkin et al. Indeed, they emphasized the need for the educational medium to match the learners' cognitive style. Several CBI advocates (e.g., Kearsley, et al., 1983; J. Olsem, personal communication, October, 1985; and Tennyson, Christiansen, and Park, 1984) have suggested that the new generations of CBI systems with intelligent programs (smart technology) can make the instructional system adaptable to students' learning styles. Olsem has claimed that these ICBIs (Intelligent Computer-based Instruction) have the capacity to modify the instructional mode to best meet the students' learning profiles. These learning profiles are determined by cognitive tests embedded in the first phase of the ICBI's instructional program.

Smart technology can also be used for accommodating students with different cognitive abilities (Allen & Merrill, 1985; and Gray et al., 1985). Smart technology programs involve interactions between students and the computer so that the type of feedback and instructional materials provided fit the students' level of knowledge (Gray et al.). They have also claimed that the promise of this technology is that each student's unique cognitive needs will be met. Unfortunately, these smart technology programs have neither been fully implemented nor tested.

Adaptive control programs--a form of smart technology--have been shown to be effective for facilitating students' learning (Avner et al., 1980; Ross, 1984; and Tennyson & Buttrey, 1980). An adaptive control is when the amount of instruction is managed by the CAI program based upon students' achievement-level, aptitude, or cognitive-style (Carrier et al, 1984) Ross has shown that such a program can accommodate individual learning differences. Furthermore, Avner et al. have claimed that adaptive control programs represent the real basis for CBI's superiority.

CMI is another adaptive control mechanism which is seemingly suitable for accommodating individual differences (Baker, 1978; Federico, 1983; and Kearsley et al., 1983). CMI can be used to advise students and teachers about the most appropriate instructional sequence for each student. Federico showed that for Navy trainees CMI programs reduced the learning variability usually associated with cognitive differences.

The supportive research for adaptive control mechanisms may be problematic. Research on smart technology applications have been experiments of short duration which have rarely compared CBI to other media. These studies have also mainly investigated CBI programs in laboratory-type settings. Questions thus remain about the relative effectiveness of smart technology programs for educational settings. And, Ross (1984) has demonstrated only limited advantages for CMI over other media for dealing with learning differences. CMI was only found to be advantageous for complicated and lengthy lessons.

Problems may also exist with using adaptive CBI programs. CMI programs are used in conjunction with either conventional instruction or CAI programs. CMI is thus useful as a supplemental but not as a primary mode of instruction. Also, Merrill et al. (1980) felt that adaptive CAI programs would ultimately be "maladaptive" for meeting students' educational needs because students' subsequent learning in non-CAI environments would become more difficult as the real world does not adapt to the student.

Individual Differences and CBI Limitations

As discussed previously, CBI may not be beneficial to all students. Several investigators (e.g., Cambre & Cook, 1985; Jay, 1981; Loyd & Gressard 1984a & 1984b; Maurer, 1983; and Wood and Pitz, 1985) have found that computer anxiety can inhibit a person's ability to successfully master computer skills; consequently, such anxiety may inhibit a student's mastery of information from a CBI system. As discussed by Cambre & Cook, the following four behaviors are associated with computer anxiety (p.52):

(1) Avoidance of the computer and general area where the computer is located.

(2) Excessive caution with the computer.

(3) Negative remarks about the computer.

(4) Attempts to cut the computer session short.

The existence of and problems associated with computer anxiety have not been systematically investigated. Loyd and Gressard (1984b) have attempted to rectify this problem in the CBI literature by devising a self-report questionnaire which measures, among other things, these cited dimensions of computer anxiety. They have claimed that this questionnaire provides an effective, reliable, and convenient measure of students' computer anxiety. Wood

and Pitz (1985), however, have suggested that any self-report questionnaire on computer anxiety (e.g., Loyd and Gressard's,) without scales for lying and social desirability may not be a valid measure, because subjects' stated expectations about using a computer are not always congruent with their actual computer behaviors. Personal experiences have also demonstrated that people may be reluctant to state their fears of using a computer.

A reliable and valid questionnaire on computer anxiety would be beneficial to both educators and researchers. Such a questionnaire would provide additional insights into explaining possible variability in students' abilities to use CBI materials. This scale would also then help educators to pinpoint those students who need additional support and guidance for using this medium. Schubert (1985), for example, found that computer anxious females had to go through a formal desensitization process before they were able to deal with the CBI materials. Consequently, the educational, temporal and financial costs associated with helping such computer anxious students should also be included in any evaluation of a CBI system.

Differences in computer experience may also differentially affect students' use of CBI materials. Carroll and his associates (e.g., Carroll, 1984; Carroll, & Mazur, 1984; and Carroll & Thomas, 1982) have noted that infrequent computer users often have difficulty in learning to use a computer system. They also suggested that embedded instructions for using a computer must relate to students' prior computer use and knowledge. CBI professionals must then consider both novice and experienced computer populations when designing and evaluating a CBI system. If the system cannot accommodate all levels of users, then a segment of students, especially the infrequent users, will not be able to use and benefit from the CBI system. There also may be extreme variability in subjects' training time on a CBI system, with infrequent users proceeding much slower then regular and frequent users. Such variability may then negate CBI's previously cited potential for reducing instructional time. This variability may decrease in military training as the number of military students taking computer literacy and CBI courses increases.

Computer experiences may also relate to computer anxiety (Loyd & Gressard, 1984a; and King, 1975). Even though the data may be problematic, Loyd and Gressard did find a significant relationship between infrequent computer use and computer anxiety. If this is so, then computer-experienced users would likely be excited and motivated to use a novel CBI program while non-experienced users might be apprehensive about using such a program. This novelty issue will be further discussed in the section on student attitudes.

Hess and his associates (e.g., Hess & Miura, 1985; Hess & Tenezakis, 1973; Miura & Hess, 1983, and Schubert, 1985) have indicated that there are sex differences associated with students' use of computers. Miura & Hess have found that middle-school boys more than girls: a) owned and used home computers and b) enrolled in computer camps and summer classes. They also asked these students to rate a number of randomly selected courseware titles as being either male of female oriented. These students rated a significantly larger number of courseware titles to be primarily suited for male

audiences and not for female audiences. Other studies, e.g., Loyd and Gressard (1984a), however, did not find gender differences to be significantly related to computer use or anxiety.

Conclusions

CBI's potential as the "ultimate individual difference machine" has not been substantiated. Even though this potential may become more evident for future CBI generations, research on current CBI programs and individual differences is plagued with confounded and contradictory findings.

Individual differences may conversely limit CBI's usefulness. As discussed, computer-anxious students are the most likely to have problems with using this medium. Finally, the educational and financial costs associated with helping students to successfully use a CBI program must also be included in a system's cost-analyses.

The most seemingly pervasive finding in the CBI literature is that students favor taking a course by this medium. Many reports (e.g., Clement, 1981; Merrill et al., 1980; and Myers, 1984) have urged implementation of CBI based upon student attitudes. Myers noted that PLATO has been enthusiastically accepted by students and teachers. Also, advertisements on CBI products have claimed that "learner motivation is high because the system is easy and fun to use." (Teaching/Learning Technologies, 1984)

As the research on students' CBI attitudinal data has rarely been examined, the robustness of the data about students' attitudes toward CBI as compared to their attitudes toward other media must be questioned. This analysis must also include examining the pyschometric attributes of the different attitudinal measures used in these studies. In this section, factors influencing students' CBI views will also be discussed.

Attitudinal Studies

Comparisons of students' attitudes toward CBI and other media have been included in some of the previously cited military studies (e.g., Dallman et al., 1977; Ford et al., 1972; Longo, 1972; and Tatsuoka & Misselt, 1978). These studies indicated that students favored taking a course by CBI rather than by other media. Longo, for example, found in two separate studies more positive ratings being exhibited by the CBI group than by the conventional instruction group.

Dallman et al. (1977) also reported that students tended to favor taking a CBI course rather than a conventional instruction course. They noted, however, that the conventional instruction course was taught by newly trained teachers. They also found that a conventional instruction course taught by a popular teacher was more favorably received than was CBI. In a second study, they failed to find any significant differences between students' attitudes toward CBI and toward programmed instructions.

Mixed results about students' preference for CBI over other instructional media were the pattern for the civilian literature. Avner and associates (Avner, 1981; and Jones, Kane, Sherwood, & Avner, 1983) in a series of course evaluations found that University of Illinois' students favored PLATO over other instructional media. For two semesters, Chemistry 100 students were asked to rate several different media with regards to helpfulness in learning the class materials. These media were PLATO, textbook, lecture, labs, and quiz sections. The main professor for this course had received several outstanding teaching honors. For both semesters, the PLATO system received the highest ratings of 4.5 on a five point scale. Differences between ratings for CBI and conventional instruction were substantial--over a point difference on a five point scale. Differences in students' ratings of CBI and Quiz

section were .9 and .4 for Fall, 1977 and Spring, 1978 semesters, respectively. These course evaluations and Dallman et al's study are some of the few studies in which students' attitudes toward CBI were compared with their attitudes toward other non-conventional modes of instruction.

Bangert-Drowns et al. (1985) and Kulik et al. (1980) demonstrated limited support for the assumption that students preferred CBI. Both meta-analyses could only find a few studies--eleven for the Bangert et al. analysis and five for the Kulik et al. analysis--which compared attitudes toward CBI and toward conventional instruction. Bangert et al. found an average effect of .09 for CBI upon secondary students' attitudes, and Kulik et al. discovered an effect of .18 favoring CBI for college instruction.

Problems with concluding that students prefer to take a CBI rather than a conventional instruction course are vividly demonstrated by Alderman et. al.'s (1978) findings. A large percentage of PLATO students indicated positive feelings toward this courseware as manifested by their desire to take another course using this system. They also disagreed that using PLATO was dehumanizing or boring. Attitudinal comparisons between PLATO and conventional instruction students, however, failed to reveal any noticeable differences in these students' feelings toward their classes. Alderman et al. also found that students reactions to TICCIT programs were usually less positive than those for the conventional instruction program. Interestingly enough, this study has been widely cited as providing evidence that CBI has a positive impact upon students' attitudes.

Magidson (1978) is another study widely cited as demonstrating that students prefer to take a CBI course. Magidson's results about PLATO users' views parallel those found by Alderman et al (1978). Over ninety percent of these students enjoyed using PLATO and would recommend that their friends take a PLATO-based course. He also reported that less than ten percent of these students found PLATO to be boring and dehumanizing. Attitudinal comparisons between PLATO and conventional instruction students were not made.

Conclusions cannot then be made about students' preference for CBI over other instructional media based upon Alderman et al's (1978) and Magidson's (1978) studies. As indicated, the previously discussed assumptions about students' desires for CBI courseware have been based on these two studies and others (e.g., Dengler, 1983; and Jenkins & Dangert, 1981) which obtained parallel results using similar methodologies. Nonetheless, these studies do suggest that students would accept taking a course by CBI.

Alderman et al's (1978) and Magidson's (1978) findings have also suggested that students do not believe that CBI is dehumanizing as an educational experience. King (1975) provided more substantial evidence for this point about CBI and the possible dehumanization threat. After thoroughly reviewing the military and civilian CBI literature on student attitudes, King concluded that CBI is not a dehumanizing instructional experience.

King (1975) also examined the data on the relationships between student attitudes and individual differences. She concluded that learner control has not been shown to significantly influence student attitudes. However, some

limited evidence was found showing that computers motivated underachievers, slower students, and potential dropouts. Mevarech and Rich (1985) also demonstrated that CBI could improve disadvantaged students' perceptions of school life. Again, these studies did not systematically compare the relative effects of CBI and conventional instruction upon problem students' attitudes.

Psychometric Attributes of Attitudinal Measures

Attitudinal data may be inconsistent because of problems with some of the instruments used in measuring these data. Knerr and Nawrocki (1978) have noted that most attitudinal instruments are designed ad hoc with neither the items not the metric properties of the scales described. As stated by King (1975):

> Most (attitudinal) studies are experimental-constructed tests which have unknown or unreported reliabilities. (p7)

For example, Jenkins and Dankert (1981) indicated that reliable data were collected; however, descriptions of the items and the test-retest reliabilities were not provided. And Bangert-Drowns et al. (1985) and Kulik et al. (1980) failed to describe the reliabilities of the different attitudinal measures reviewed in their reports.

Several of the previously cited studies (e.g., Avner, 1981; Dallman et al. 1977; Knerr & Nawrocki 1978; Longo, 1972; Loyd & Gressard 1984b and Mevarech & Rich, 1985) have developed or used attitudinal measures with apparently sufficient reliabilities. Mevarech and Rich measured students' perceptions of the instructional environment with a questionnaire developed by Epstein and McPartland (1976). This questionnaire had a known internal consistency coefficient of .84. Longo reported nearly identical attitudinal scores on the same items for two separate studies, which indicates that the measures were reliable. Perhaps, then, potential reliability problems with attitudinal measures can be eliminated by using established questionnaires or by replicating the results. Other than the few studies cited in this report (e.g., Dallman et al's, 1977 and Longo's), a lack of replicated findings comparing CBI to other media exists in this research literature.

Avner (1972) argued that reliability for attitudinal measures should not be determined by using a large number of items selected for internal consistency. Rather, a highly reliable single item should be used for each attitude to be measured. He has claimed that reducing the number of items allows the researcher to sample student opinions more frequently without encroaching on the students' good will or the limited class time available. And reliability measures which are based upon internal consistency can be a misleading indication of the questionnaire's value, because such a group of items can only be vaguely interpreted. Except for a few studies conducted by Avner and associates, the reliability of single item attitudinal measures has rarely been determined.

Problems may also exist with the validity of the attitudinal measures used in CBI research. Discrepancies between students' responses to questionnaires and more objective data have been found by Knerr & Nawrocki (1978); Shlechter (1985); and Wood and Pitz (1985). Shlechter, for example, noticed that soldiers reported that using a light pen was relatively easy, when in fact many of their errors related to problems with using this responding mechanism. Additional efforts to compare self-reports with objective performance measures seem warranted. As stated by Avner (1972):

> While the questionnaire provides a convenient and useful method of gathering student data in certain situations (e.g., students' learning to use a system) there is no alternative to direct observation of student behavior (p5).

Bessemer (personal communication, October 31, 1985) has suggested that attitudinal data must be validated by students' actual use of an implemented system.

Another threat to CBI attitudinal measures is that items regarding social desirability are not included. This problem is especially important for studies (e.g., Dallman et al. 1977; and Tatsuoka and Misselt, 1978) in which instructors have been part of the evaluation process. Reasons for including a social desirability measure will be elaborated upon in the next few pages.

Problematic attitudinal measures are frequently found in the CBI literature. As indicated, psychometric problems with these measures were observed in studies with favorable and in studies with neutral outcomes about student's preference for CBI. These measurement problems tend to further limit conclusions about CBI and student attitudes.

Factors Affecting Student Attitudes

The main factor affecting students' attitudes should be the CBI program's instructional value. Gleason (1981) has claimed that students do react very positively to good CBI programs and reject poor programs. Clement (1981) has also noted that CBI lesson materials which reduce student error rates may be beneficial to maintaining and producing positive attitudes. Clement and Gleason however, do not provide any data supporting their positions.

Limited evidence exists about the effects of performance upon student attitudes. King (1975) reported only one study (Mitzel & Wodtke, 1965) which examined the relationship between attitudes and performance. Mitzel & Wodtke found that a significant positive correlation existed between these variables. On the other hand, Tatsuoka and Misselt (1978) could not find any substantial relationships between military students' gain-scores on a CBI training program and attitudinal measures. This study investigated students' CBI use and their attitudes toward four different courses at Chanute Air Force Base. Correlations between students' gain-scores and attitudinal indexes of instructional effectiveness and positive affect were not significant at levels of .19 and .21, respectively. Significant correlations ($p < .05$) of .32 and -.29 for the instructional effectiveness and positive affect

variables, respectively, were found when a multiple regression technique was used to determine the correlational coefficients. The .19 and .32 correlations dealt with students' perceptions of PLATO's effectiveness and performance while the other two correlations involved students' positive feelings toward CBI and performance. Tatsuoka and Misselt never explained the reason for the directional shift in the second set of correlations. Also, as reported, Alderman et al. (1978) found that students had less favorable attitudes toward TICCIT than toward conventional instruction, but TICCIT was found to be more effective for some educational measures. A link then has not been found between attitudes and instructional quality.

A link does seem to exist between users' attitudes and human factors issues (Avner, 1986, King, 1975; Magidson, 1978; McVey, Clauer, & Taylor, 1984; Shlechter, 1985; and Tatsuoka & Misselt, 1978). Avner found correlations of .80 between users' (28 instructors) ratings and system reliability. He also found a significant point-biseral correlation of .593 between instructors' ratings and the decision to continue/discontinue the use of the PLATO system. Tatsuoka and Misselt found correlations of .-43 and -.45 between students' perceptions of mechanical failures and students' attitudes toward the system's acceptability and instructional effectiveness, respectively. McVey et al., discussed the possibility that hardware features might affect users' comfort. As stated by McVey et al.:

> A thorough review paper by Campbell and Durden (1983) suggests that there are many overlooked factors contributing to the humorous accusation that VDT (CRT) means "Visual Discomfort Terminals." (p1)

Other reports from the human factors literature (e.g., Dainoff, Happ, & Crane, 1981; IBM, 1984; Helander & Rupp, 1984; and Rupp, 1981) have also discussed problems with CRTs. Dainoff et al. found that visual fatique was more pronounced among typists using CRTs than for typists using print-based terminals. They also noted that these differences in visual fatique were not related to amount of work or other job pressures.

Different CRT standards have been recently developed by different countries and agencies, e.g., Department of Defense (DoD) to control for possible problems with the design of these terminals (Helander & Rupp, 1981). Unfortunately, as noted by Helander and Rupp, the DoD standards have emphasized productivity over operator comfort and convenience. Possible instructional inefficiency, however, may be associated with "visual discomfort terminals" as students may not be able to use these terminals for an extended period of time. Reliable attitudinal data are needed for ascertaining specific problems that students may have with the CBI system.

Useful information about CBI programs has been obtained when attitudinal measures have been used to ascertain specific issues. Tatsuoka and Misselt (1978) found that students' responses to open-ended attitudinal questions were helpful in revising poorly developed CBI lessons. Avner (personal communication, November 1985) discovered through such open-ended responses positive attributes of CBI, such as scheduling flexibility for students, which would not have been discovered through other procedures. And Shlechter

(1985) found through students' interview responses that a particular system might be best used as a supplement to the conventional instructional program. Attitudinal measures, especially open-ended questions, may then be most useful for providing formative feedback about students' perceptions of a system's strengths and weaknesses.

Factors other than the CBI system may unduly influence students' attitudes. Abrami and Mizener (1982) noted that teacher attitudes had a substantial effect upon students' attitudes in conventional instruction courses. Avner (1985) demonstrated that teachers' attitudes toward CBI did effect students' attitudes toward the system. Avner used exemplary and mediocre CBI courseware, as judged by a panel of CBI professionals. He found that students initially judged both programs to be either positive or negative depending upon the teachers' positive or negative feelings toward the system. An examination of the data, however, indicated that students who had teachers with positive attitudes toward CBI still--after a month's period--maintained positive attitudes toward the mediocre program. Also, these students had slightly more positive attitudes toward CBI than the students in the exemplary CBI materials-hostile teacher condition. Teachers'attitudes could then confound students' CBI attitudinal data.

Because of the unique relationship between military instructors and their students, evaluations of military CBI programs would be especially prone to problems associated with instructor attitudes. Military instructors need to be involved in the evaluation process. Draxl and Aggen (1981), and Gray (1986) have described the need to give briefings to enlist military instructors interest in, and support of, new instructional systems. Military instructors' attitudes--as civilian instructors' attitudes--may also be influenced by their superiors' beliefs. Indeed it is hard to imagine how these instructors can remain neutral toward CBI when their superiors, e.g., Sullivan (1985), have indicated that this medium will be an integral part of all future Army training. Such briefings by CBI evaluators and Army staff may engender positive attitudes in instructors, while militating against obtaining unbiased reports from students. Military students may be more reluctant than civilian students to state their dislike of a CBI system, because military instructors have much more power over their students than do conventional teachers. This possible difference between military and civilian students can explain why more favorable comments toward CBI have been found in the military training literature than in the civilian literature.

Another possible confounding in attitudinal research is novelty effects. As previously reported, Clark (1983 and 1985a) has claimed that students are initially motivated and enthusiastic to learn from a new CBI program. Questions, though, remain about a system's ability to sustain students' interest and motivation. Pagliaro (1983), in a year-long study of a CBI program for pharmacology students, found that these students reported the system to be significantly less interesting across testing periods. The magnitude of the decrements in students' ratings, however, was not great.

Other CBI reports (e.g., Avner, 1985; Ford et al. 1972; King, 1975; and Magidson, 1978) have not been able to find any substantial effects for CBI experience upon attitudinal data. Ford et al. found that long-term CBI users'

attitudes toward CBI were more positive than the attitudes of first-time users. The long-time users were fifty students out of more than 200 sampled who had prior experience with CBI. Avner showed that subjects across the different experimental conditions reported more positive attitudes toward the CBI system with increased usage. Thus, novelty effects as defined by length of CBI experience do not seem to have a major influence upon students' attitudes.

Clark and his associates (e.g., Clark & Salomon, 1985) also suggested that students would prefer any newer instructional technologies over the established ones--"program novelty effects." Support for "program novelty effects" comes from Simonson's (1980) extensive review of the CBI literature. Simonson has concluded that students seemingly prefer to learn from any new instructional mode, e.g., instructional T.V. or programmed instruction, over conventional instruction. Shlechter (1985) reported that students preferred a CBI system to conventional instruction because of the individualized instruction associated with this system. These students would then seemingly prefer any individual mode of instruction over conventional instruction. As has been previously argued, individualized instruction characterizes nearly all modern instructional innovations.

Juola (1977) reported findings which conflicted with those previously cited about new media and student attitudes. Seven hundred freshmen at Michigan State University found instructional television and programmed instruction to be undesirable instructional media. Juola's study, however, is not typical of this research literature. Future research is needed in which students' CBI attitudes are compared with attitudes for other: (a) equivalent instructional media and (b) new instructional modes.

Conclusions

Inconsistent and confounding findings are predominate in the CBI attitudinal findings. Furthermore, these problematic findings seem to relate to factors other than courseware differences. CBI systems should not be implemented based primarily upon attitudinal data. Recommendations have also been made about using attitudinal data for formative feedback, making attitudinal comparisons with other new and equivalent instructional technologies, using objective measures to validate the subjective attitudinal measures, and conducting more naturalistic attitudinal studies. Such naturalistic studies would ultimately provide CBI professionals with the most useful data about CBI and student motivation.

Summary and Recommendations

Consistent empirical support does not exist for the claimed advantages of CBI over other instructional media for: a) reducing training time; b) reducing life cycle costs; c) facilitating students' mastery of the instructional materials; d) accommodating individual learning differences; and e) motivating students' learning. The lack of empirical support for these issues is not totally explained by problematic courseware. As discussed, some courseware was created by some of the finest instructional designers. And some benefits of CBI, e.g., training-reductions, have been attributable to instructional features which are inherent in any individualized instructional media. CBI's inherent superiority as a primary instructional medium has thus not been established.

Notwithstanding these mixed findings, future generations of CBI, e.g., ICBI, do promise to have a significantly positive impact upon students' cognitive processes. This medium also promises to help slow learners. Unfortunately, problematic research practices prohibit any conclusions about CBI and slow learners. Also, CBI does not seem to be a dehumanizing instructional experience.

Problematic research procedures were also found throughout the CBI literature. Most noticeable of these research problems were: a) confoundings due to differences in instructional content; b) making comparisons with inappropriate media; c) confoundings due to "program novelty effects" and "teacher attitudes;" and d) findings which were not replicated. Recommendations have also been made that future CBI evaluations: a) be conducted on fully implemented systems; b) examine hidden life cycle costs for each implementation; c) examine the effects of human factors variables upon a system's cost-effectiveness; d) examine the effects of human factors variables upon students' comfort; e) examine students' abilities to transfer the instructional information; f) measure the unwarranted additional instructions associated with the experimental or control treatments; g) control for possible confoundings due to insufficient testing durations; h) examine interactions between students' characteristics and specific delivery features and CBI systems; and i) use attitudinal data for formative but not summative evaluation. Clearer answers about CBI's inherent value--in general and for specific system's--would be obtained if future CBI investigations deal with the research problems and recommendations cited in this paragraph.

This paper's methodological issues reflect the complexities in CBI evaluation. Ideally, CBI evaluations should be done by a team of professionals from various disciplines--military or civilian education, human factors, educational psychology, and instructional technology. Also some time consuming and expensive evaluation procedures must be employed. To the extent that CBI evaluation is used to compare CBI to other instructional media, especially conventional instruction, then both cross-sectional and longitudinal data should be collected. A cross-sectional design is needed for initial assessments of students' CBI performance, while longitudinal data are necessary to

ascertain the long-term learning and attitudes associated with the CBI system. The longitudinal data can also be used as a reliability check. Systematic programs are needed in which priorities are assigned to independent variables and variables are systematically manipulated and measured in successive studies using the same CBI system. The systematic analyses would provide information about the relationship between estimated and life cycle costs. Also programmatic research is needed to provide further insights into the question of whether the cited CBI limitations are due to courseware or hardware problems.

Another issue in CBI evaluations concerns the traditional use of formative evaluations for debugging the CBI's programs problem areas. Williges, Williges, and Elkerton (in press) have noted that formative evaluation is central to the design of any computer system. They fail, however, to mention the necessity for conducting a similar formative evaluation upon the existing or comparative instructional system(s). These discrepant evaluation procedures will certainly lead to the possibility of making confounded comparisons because the CBI program is operating at optimal efficiency while the same cannot be said for the comparative media.

Formative evaluations should also be conducted after the initial experimental data have been collected, rather than as traditionally done prior to the experimental process. Such formative evaluation data could help determine the reasons for the experimental findings. Furthermore, the formative data could also help determine the research program's next phase. As suggested by Boldovici and Scott (1984), evaluators should thus initially determine the CBI system's relative efficiency and then pinpoint the reasons that the system was more, less, or equally effective than was the comparative media. The evaluator's role is to assess objectively a system's instructional value and not to help with the design process.

Financial, temporal, and personnel limitations may prohibit the extensive evaluation procedures recommended in this report. Needless CBI studies could be eliminated if the evaluation team could build upon the works done by other teams on that system. Presently, communications problems among CBI professionals present an obstacle to this building process. Many previous evaluations of CBI systems are not easily available. Bangert-Drowns et al's (1985) meta-analysis of the CBI literature included only six published studies out of more than forty studies examined. This author also found that many CBI reports could only be found through corporation and military archives. And some studies which showed unfavorable results regarding a CBI system's effectiveness were not available for distribution.

A CBI handbook, such as Buros' Mental Measurement Yearbooks, is needed to provide a common information source for CBI professionals about different CBI systems and corresponding evaluations. This handbook should include a detailed description of the studied sample, research instruments, research procedures, and findings. Such information would help prospective CBI implementers to determine the best system for their instructional needs, or to discover that previous CBI evaluations might not be transferable to their situations. The military has tried to establish such a CBI library with the

TRIADS program (see Dallman et al., 1983 for a description of this program); however, TRIADS consists of a library of CBI programs without corresponding evaluation data.

Questions do remain about the optimal situations for implementing a CBI system. As indicated throughout this report, CBI may be best used as an instructional tool to supplement the established instructional program rather than as the primary instructional medium. Yet, using CBI to supplement rather than replace other instructional modes raises further questions about the costs associated with this medium. If CBI can help problem learners than it would be worth the additional expenditures.

Another situational aspect involves determining the appropriate CBI system for the instructional situation. The Army, for example, must decide on such options as using a hand-held tutor or microcomputer system to teach maintenance students. With all these research decisions, evaluators would do better to shift focus from questions of the inherent superiority of CBI to the identification of conditions under which CBI and alternative media produce and do not produce the desired results. Various media have various strengths which must be first enumerated and then matched with intended instructional settings, objectives, and resources.

Widespread implementation of CBI for all educational situations is not recommended. Such indiscriminate use of CBI could lead to the abandonment of this instructional technology, because the research evidence has indicated that at present the promises may outweigh this medium's potential. CBI may be useful as an instructional tool which can help make established instructional program more effective. And CBI researchers must help determine those situations for which instructors can best use this medium.

Conclusions

In closing, CBI's effectiveness over other alternative media for military training has yet to be established. CBI can provide the military with standardization of instruction and provide reserve components with needed sustainment training. Also future generations of CBI, especially ICBI's, with potential advances in hardware, software, and courseware design could make this medium more effective. The military research community must be more careful in conducting future CBI evaluations and must be careful not to overstate the promises of this medium. Researchers of military training programs should also focus upon determining the learning tasks most suitable for CBI, and should concentrate on helping the military education community to most effectively integrate computers in already established instructional programs.

Final Implications

1. Consistent evidence does not exist to support the instructional superiority of CBI over other media.

2. Future generations of CBI, such as ICBI, promise to help students' cognitive processes. This medium also promises to help slow learners. Unfortunately, problematic research practices prohibit any conclusions about CBI and slow learners.

3. Problematic research procedures are found throughout this literature.

4. The methodological recommendations discussed in page 31 must be incorporated in future CBI evaluation.

5. The evaluation team ideally would consist of professionals from various disciplines.

6. Programmatic research on CBI systems should be conducted which includes both cross-sectional and longitudinal studies.

7. Formative evaluation should be conducted on the different media being compared.

8. Formative evaluation should be conducted upon completion of the initial experimental study.

9. A CBI handbook should be developed which contains information about previous CBI evaluations.

10. CBI researchers should shift focus from examining the inherent superiority of this medium to identifying conditions for using computers in the instructional process.

11. Widespread implementation of CBI for all educational situations is not recommended.

References

Abrami, P.C., & Mizener, D.A. (1982, August). Student/instructor attitude similarity, course ratings and student achievement (Document No. HE-015-572). Paper presented at the Annual Meeting of the American Psychological Association, Washington, D.C.

Alderman, D.L., Appel, L.R., & Murphy, R.T., (1978, April). PLATO and TICCIT: An evaluation of CAI in the community college. Educational Technology, 18, 40-46.

Alderman, D.L. (1974, April). Planning for the evaluation of the PLATO and TICCIT computer-based instructional systems: The comparison of performance for community college students. A paper presented at the Annual Meeting of the American Educational Research Association, Chicago.

Allen, B.S., & Merrill, M.D. (1985). System-assigned strategies and CBI. Journal of Educational Computing Research, 1, 3-21.

Avner, R.A. (1972). Student attitudes toward PLATO, survey results. unpublished evaluation report. Urbana: University of Illinois.

Avner, R.A. (1978). Cost-effectiveness of CBE. Educational Technology. 17(4), 24-26.

Avner, R.A. (1979). Production of computer-based instructional materials. In H.F. O'Neil Jr (Ed.). Issues in instructional systems development (ch. 7, pp 133-180). New York: Academic Press, Inc.

Avner, R.A. (1981, February). (Update on PLATO-based physics teaching). Unpublished data. Urbana: University of Illinois.

Avner, R.A. (1985). (Effects of teachers' CBI attitudes upon student attitudes). Unpublished data. Urbana: University of Illinois.

Avner, R.A. (1986). (Reliability of CBI and user attitudes). Unpublished data. Urbana: University of Illinois.

Avner, R.A., Moore, C., & Smith, S. (1980, May). Active external control: A basis for the superiority of CBI. Journal of Computer-Based Instructions, 6(4), 115-118.

Avner, R.A., Smith, S., & Tenczar, P. (1984). CBI authoring tools: Effects on productivity and quality. Journal of Computer-Based Instruction, VOL 11, No 3, 85-89.

Baker, F.B. (1978). Computer-Managed Instruction: Theory and practice. Englewood Cliffs, NJ: Educational Technology Publications.

Bangert-Drowns, R.C., Kulik, J.A., & Kulik, C-L., C. (1985). Effectiveness of computer-based education in secondary schools. Journal of Computer--Based Instruction, 12(3), 59-68.

Barsam, H.F., & Simutis, Z.M. (1984). Computer-based graphics for terrain visualizations training. Human Factors. 26(4), 659-665.

Bass, G., Reiss, R. & Sharpe, W. (1986). Teaching basic skills through microcomputer assisted instruction. Journal of Educational Computing Research, 2(2), 207-219.

Bellinger, K. (1986, February). CAI as part of the total faculty development package. Paper presented at the Twenty Seventh International Association for the Development of Computer-Based Instructional Systems, New Orleans.

Bialo, E.R., & Erickson, L.B. (1984, April). Microcomputer courseware: Characteristics and trends. Paper presented at the Annual Meeting of the American Educational Research Association, New Orleans.

Boldovici, J. A., & Scott, T. (1984). The Hewlett-Packard HP-41CV Hand-Held Computer as a medium for teaching mathematics to fire control systems repairers. (ARI Research Report 1408; ADA160440).

Bunderson, C.V. (1981). Courseware. In H.F. O'Neil, Jr., (Ed.), Computer-based instruction: A state-of-the-art assessment (Ch.4, pp. 91-125). New York: Academic Press.

Burger, K. (1985). Computer-Assisted instruction: Learning style and academic achievement. Journal of Computer-Based Instruction, 12(1), 21-25.

Burnside, B. (1985, July-August). Using technology to train the TC (tank commander). Armor: The magazine of mobile warfare, 94(4), 42-45.

Cambre, M.A., & Cook, D.L. (1985). Computer anxiety: Definition, measurement and correlates. Journal of Educational Computing Research, 1(1), 2[illegible]-36.

Campbell, F., & Durden, E. (1983). The visual display terminal issue: A consideration of its physiological, psychological, and clinical background. Opthalmology and Psysiological Optics, 3, 175-192.

Card, S.K., English, W.K., & Burr, B.J. (1978). Evaluation of mouse, rate-controlled isometric joystick, step keys, and text keys for text selection on a CRT. Ergonomics, 21(8), 601-613.

Carrier, C.A. (1979). The role of learner characteristics in computer based instruction. National Society for Programmed Instruction Journal, 18(5), 25, 22.

Carrier, C., Davidson, G., Higgson, V., & Williams, M. (1984). Selection of options by field independent and dependent children in a computer-based concept lesson. Journal of Computer-Based Instruction, 11(2), 49-54.

Carroll, J.M. (1984, May). Mental models and software factors (RC 10616 (#47016)). Yorktown Heights, NY: IBM Watson Research Center.

Carroll, J.M., & Mazur, S.A. (1984). Learning to use an office system with an on-line tutorial (RC 106445(#47740)). Yorktown Heights, NY: IBM Watson Research Center.

Carroll, J.M., & Thomas, J.C. (1982). Metaphor and the cognitive representation system, IEEE Transactions on Systems, Man, and Cybernetics, 12(2), 107-116.

Chapanis, A. (1965). Words, words, words. Human Factors, 7(1), 1-17.

Chapanis, A. (1985). Human factors methodology. In R.W. Pew and P. Green (Eds.), Human Factors Engineering Short Course (26th ed.), (Lecture 4). Ann Arbor: Univeristy of Michigan, Chrysler Center for Continuing Engineering Education.

Christiansen, J.M. (1985, July-August). Human factors considerations in reliability and maintainability. In R.W. Pew and P. Green (Eds.), Human Factors Engineering Short Course Notes (26th ed.), (lecture 9). Ann Arbor: Univeristy of Michigan, Continuing Engineering Education, Engineering Summer Conferences.

Clark, B. (1983). Growing up gifted (second edition). Columbus, OH: E. Merrill Publishing Company.

Clark, R.E. (1983). Reconsidering research on learning from media. Review of Educational Research, 53(4), 445-459.

Clark, R.E. (1984). Research on student thought processes during computer-based instruction. Journal of Instructional Development, 7(3), 2-5.

Clark, R.E. (1985a). Confounding in educational computing research. Journal of Educational Computing Research, 1, 389-394.

Clark, R.E. (1985b). The importance of treatment explication: A reply to J. Kulik, C-L. Kulik and R. Bangert-Drowns. Journal of Educational Computing Research, 1, 389-394.

Clark, R.E., & Leonard, S. (1985, March). Computer research confounding. Paper presented at the annual meeting of the American Educational Researh Association, Chicago.

Clark, R.E., & Salomon, G. (1985). Media in teaching. In M.C. Wittrock (Ed.), Third handbook of research on teaching, (Vol. 3) (pp. 464-477). New York: McMillian.

Clark, R.E., & Voogel, A. (1985, Summer). Transfer of training principles for instructional design. Educational Communication and Technology Journal, 113-123.

Clement, F.J. (1981, April). Affective considerations in computer-based education. Educational Technology, 28-32.

Cleveland Public Schools (1981). Disadvantaged public program fund evaluation. Final Report. (ERIC Document Reproduction Service No. ED 211-637).

Collier, R.R., Poyner, L., O'Neil Jr., H.F., & Judd, W.A. (1973, February). Effects of learner control on performance and state anxiety in a computerized concept learning task. Paper presented at the Annual Meeting of the American Educational Research Association, New Orleans.

Craik, F.I.M., & Lockhart, R.S. (1972). Levels of processing: A framework for memory research. Journal of Verbal Learning and Verbal Behavior, 11, 671-684.

Dainoff, M.J., Happ, A., & Crane, P. (1981). Visual fatique and occupational stress in VDT operators, Human Factors, 23(4), 421-438.

Dallman, B.E., DeLeo, P.J., Main, P.S. & Gillman, D.C. (1977). Evaluation of PLATO IV in vehile maintenance training (Report No. AFHRL-TR-77-59). Chanute Air Force Base, IL: USAF School of Applied Aerospace Sciences, Training Research Applications Branch.

Dallman, B., Pohlman, D., Psotka, J., Wisher, R., McLachlan. J., Wulfeck, W., Ahlers, R., & Cronholm, J. (1983). TRIADS: A foundation for military computer-based instruction. Journal of Computer-Based Instruction, 10(3-4), 59-61.

Dengler, P.E. (1983). Computer-assisted instruction and its use in occupational therapy education (automated instruction, PLATO, self-study, tutorial). The American Journal of Occupational Therapy, 37, 255-259.

Draxl, M., & Aggen, W. (1981). Computer-based instruction project: Final report (Contract No. DAJA 37-79-C-0483). University of Maryland, European Division.

Eberts, R., & Brock, J.F., (1984). Computer applications to instruction. In F.A. Muckler (Eds.), Human Factors Review 1984 (239-284). Santa Monica: The Human Factors Society.

EDUCOM Bulletin, Summer 1983, p. 29.

Epstein, J.L., & McPartland, J.M. (1976). The concept and measurement of quality of school life. American Educational Research Journal, 50, 13-30.

Farr, B.J. (1985, March). The Job-Skills Education Program (JSEP): Systems for Army Education. Paper presented at the International Conference of the Association for the Development of Computer-based Instructional Systems, Philadelphia.

Federico, P-A (1983). Changes in the cognitive components of achievement as students proceed through computer-managed instruction. Journal of Computer-Based Instruction, 9(4), 156-168.

Fishman, D.J. (1985). Interactive video: The next frontier. Proceedings of the Twenty Sixth International Association for the Development of Computer-Based Instructional Systems (pp. 144-148). Bellingham: Western Washington University.

Fletcher, J.D. & Rockway, M.R. (1986). Computer-based training in the military. In J.A. Ellis (Ed.), Military contributions to instructional technology (pp. 171-213). New York: Praeger.

Ford, J.D., Jr., Slough, D.A., & Hurlock, R.E. (1972). Computer assisted instruction in Navy technical training using a small dedicated computer system: Final report (Research Report SRR 72-13). San Diego: Naval Personnel and Training Research Laboratory.

Francis, L.D., Welling, L.G., and Levy, G.W. (1983). An evaluation of the CAI (Computer-Assisted Instruction) segments of the TOW Field Test Site and the HAWK CW Radar Repair Course (TDI-TR-83-3). Fort Monroe, VA: US Army Training and Doctrine Command.

Gay, G. (1985, April). Interaction of learner control and prior conceptual understanding in computer-assisted video instructions. Paper presented at the Annual Meeting of the American Educational Research Association, Chicago.

Gleason, G.T. (1981, March). Microcomputers in education: The state of the art. Educational Technology, 7-18.

Gray, W.D. (1986). A role for evaluators in helping new programs succeed. In J.S. Wholey, M.A. Abramson, & C. Bellavita (Eds.), Performance and credibility: Developing excellence in public and nonprofit organizations (pp. 149-163). Lexington, MA: D.C. Heath and Company.

Gray, W. D., Pliske, D. J., & Psotka, J. (1985). Smart technology for training: Promise and current status. (ARI Research Report 1412; ADA171423).

Gump, P. (1985, April). An environmental perspective on classroom order. Paper presented at the Annual Meeting of the American Educational Research Association, Chicago.

Hansen, J.B. (1972). An investigation of cognitive abilities, state anxiety, and performance in a CAI task under conditions of no feedback, feedback, and learner control (Document No. EM 010-722). Austin: Texas University, Computer-Assisted Instruction Laboratory.

Helander, M.G., & Rupp, B. (1984, September). An overview of standards and guidelines for visual display terminals. Applied Ergonomics, 185-195.

Hemphill, M.R. (1986, February). The impact of computer technology on self-instructional materials in speech communication. Paper presented at the Twenty Seventh International Association for the Development of Computer-Based Instructional Systems, New Orleans.

Hess, R.D., & Miura, I.T. (1985, March). Gender differences in enrollment in computer camps and classes. Unpublished Manuscript. Stanford, CA: Stanford University.

Hess, R.D., & Tenezakis, M.D. (1973, Fall). Selected findings from "the computer as socializing agent: Some socio-affective outcomes of CAI." AV Communication Review, 21(3), 311-325.

Himwich, H.A. (1977). A comparison of the TICCIT and PLATO systems in a military setting (Contract No. DAHC 15-73-C-0077). Urbana: University of Illinois, Computer-Based Research Laboratory.

Hofstetter, F.T. (1983). The cost of PLATO in a university environment. Journal of Computer-Based Instruction, 9, 148-155.

Holmes, G. (1982, September). Computer-assisted instruction: A discussion of some issues for would-be implementors. Educational Technology, 7-12.

IBM (1984, November). Human factors of workstations with visual displays. San Jose: IBM Human Factors Center.

Jay, T.B. (1981). Computerphobia: What to do about it. Educational Technology, 21, 47-48.

Jacobs, R.L., Byrd D.M., & High, W.R. (1985). Computerized testing: The hidden figures test. The Journal of Educational Computing Research, 1(2), 173-178.

Jelden, D.L. (1985, March). Effectiveness of Phoenix as a computer based education system. Proceedings of the Twenty Sixth International Association for the Development of Computer-Based Instructional Systems (pp. 50-55). Bellingham: Western Washington University.

Jenkins, T.M., and Dankert, E.J. (1981, March). Results of a three-month PLATO trial in terms of utilizations and student attitudes. Educational Technology, 44-47.

Johnson, K., & Plake, B. (1980, July). Evaluation of PLATO library instructional lessons: Another view. Journal of Academic Librarianship, 6, 154-158.

Jones, L.M., Kane, D., Sherwood, B.A., & Avner, R.A. (1983, June). A final-exam comparison involving computer-based instruction. American Journal of Physics, 51(6), 533-538.

Judd, W.A., Daubek, K., & O'Neil Jr., H.F. (1975, April). Individual Differences in learner controlled CAI. Paper presented at the Annual Meeting of the American Educational Research Association, Washington, D.C.

Juola, A.E. (1977). Student influence and higher education (Document No. HE-013-030). East Lansing: Michigan State University, Learning and Evaluation Service.

Kearsley, G., Hunter, B., & Seidel, R.J. (1983). Two decades of CBI research: What have we learned (Professional Paper 3-83). Alexandria, VA: Human Resources Research Organization.

Kemner-Richardson, S., Lamos, J.P., & West, A.S. (1984). The CAI decision handbook. Lowry AFB, CO: US Air Force Human Resources Laboratory.

Kern, R.P. (1985, April). Design of computer-based tutorials: Training students to apply cognitive processing skills in the context of tactical training. Paper presented at the Air Force Conference on Technology in Training and Education, Colorado Springs.

King, A.T. (1975). Impact of computer-based instruction on attitudes of students and instructors: A review (AFHRL-TR-75-4). Brooks AFB, TX: US Air Force Systems Command.

Knerr, B. W., & Nawrocki, L. H. (1978). The measurement of military student attitudes toward computer-assisted instruction. (ARI Research Memorandum 78-18; ADA077966).

Kopstein, F., & Seidel, R.J. (1969). Computer-administered instruction versus traditionally administered instruction: Economics. In R.C. Atkinson and H.A. Wilson (Eds.), Computer-assisted instruction (pp 327-359). New York: Academic Press.

Kosslyn, S.M. (1981). The medium and the message in mental imagery: A theory. Psychological Review, 88, 46-66.

Kulik, J.A., Kulik, C-L. C., & Bangert-Drowns, R.L. (1985). The importance of outcome studies: A reply to Clark. Journal of Educational Computing Research, 1, 381-387.

Kulik, J.A., Bangert, R.L. & Willaims, G.W. (1983). Effects of computer-based teaching on secondary school students. Journal of Educational Psychology. 75(1), 19-26.

Kulik, J.A., Kulik, C-L. C., and Cohen, P.A. (1980). Effectiveness of computer-based college teaching: A meta-analysis of findings. Review of Educational Research, 50(4), 525-544.

Landhauer, T.K. (1982). Discussant comments on trends in everyday memory research. In T.M. Shlechter, D.J. Herrman, & M.P. Toglia (Chairs), Current trends in everyday memory research. Symposium conducted at the Annual Meeting of the American Psychological Association, Washington, D.C.

Longo, A.A. (1972). A summative evaluation of computer assisted instruction in U.S. Army Basic Electronics Training (Technical Report No. 72-1). Fort Monmouth, NJ: U.S. Army Signal Center & School, Computer Assisted Instruction Division.

Loyd, B.H., & Gressard, C. (1984a, February) The effects of sex, age and computer experience on computer attitudes. Paper presented at the Annual Meeting of the Eastern Educational Research Association, West Palm Beach, FL.

Loyd, B.H., & Gressard, C. (1984b). Reliability and factorial validity of computer attitude scales. Educational and Psychological Measurement, 44(2), 501-506.

Magidson, E.M. (1978, August). Students' assessment of PLATO: What students like and dislike about CAI, Educational Technology, 18, 15-18.

Maurer, M.M. (1983). Development of validation of a measure of computer anxiety. Unpublished Master's Thesis. Ames: Iowa State University.

McDonald, B.A., & Crawford, A.M. (1983). Remote site training using microprocessors. Journal of Computer-Based Instruction, 10, 83-86.

McLaughlin, D.H. (1985, April). Computers and teaching thinking skills. Paper presented at the Annual Meeting of the American Educational Research Association, Chicago.

McVey, B.W., Clauer, C.K., & Taylor, S.E. (1984). A comparison of antiglare filters for positive and negative image displays, (HFL-50). San Jose: IBM Human Factors Center.

Merrill, M.D., Schneider, E.W., & Fletcher, K.A. (1980). The instructional design library (volume 40): TICCIT (pp 3-15, 117-127). Englewood Cliffs, NJ: Educational Technology Publications.

Mevarech, Z.R., & Rich, Y. (1985). effects of computer-assisted instruction on disadvantaged pupils' cognitive and affective development. Journal of Educational Research, 79(1), 5-11.

Mitzel, H.E., & Wodtke, K.H. (1965). Development and presentation of four different college courses by computer teleprocessing (Report R-1). State College: Pennsylvania State University, CAI Laboratory.

Miura, I.T., & Hess, R.D. (1983, August). Sex-differences in computer access, interest, and usage. Paper presented at the Annual Meeting of the American Psychological Association, Anaheim.

Montague, W.E. (1984). Computer-based systems for Navy classroom training (Report No. NPRDC TR85-11). San Diego: Navy Personnel Research and Development Center.

Montague, W.E., & Wulfeck II, W.H. (1984). Computer-based instruction: Will it improve instructional quality? Training Technology Journal, 1(2), 4-19.

Montague, W.E., Wulfeck, W.H. II, Ellis, J.A. (1983). Quality CBI instruction depends on quality instructional design and quality implementation. Journal of Computer-Based Instruction, 10, 90-93.

Morrison, J.E., & Witmer, B.G., (1983, Autumn). A comparative evaluation of computer-based and print-based job performance aids. Journal of Computer-Based Instruction, 10(3 & 4), 73-75.

Meyers, R. (1984). PLATO: Historical roots, current applications and future prospects. Training Technology Journal, 1(2), 33-37.

Niemiec, R.P., & Walberg, H.J. (1985). Computers and achievement in the elementary schools. Journal of Educational Computing Research, 1, 435-550.

Okey, J.R. & Majer, K. (1976). Individual and small group-learning with computer-assisted instruction. AV Communication Review, 24(1), 79-86.

Olson, D., & Bruner, J. (1974). Learning through experience and learning through media. In D. Olson (Ed.), Media and symbols: The forms of expression, communication and education (73rd yearbook of the National Society for the Study of Education). Chicago: University of Chicago Press.

Orlansky, J. (1983, September). Effectiveness of CBI: A different finding. Electronic Learning, 6, 59-60.

Orlansky, J. (1985). The cost-effectiveness of military training. Proceedings of the symposium on the military value and cost-effectiveness of training (pp 1-17). Brussels, Belgium: NATO.

Orlansky, J. & String, J. (1981, second quarter). Computer-based instruction for military training. Defense Management Journal, 46-54.

Pagliaro, L.A. (1983). CAI in pharmacology: Students academic performance and instructional interactions. Journal of Computer-Based Instruction, 9(4), 131-144.

Park, O. & Roberts, F.C. (1985, April). Effects of guided instructional strategies in computer-based instruction. Paper presented at the Annual Meeting of American Educational Research Association, Chicago.

Phillips, R.J., Burkhardt, H.M., Coupland, J., Fraser, R., Pimm, D., & Ridgway, J. (1984). Computer-aided teaching. Ergonomics, 27(3), 243-258.

Ragsdale, R.G. (1982, May). The computer threat to educational technology. (Document No. IR 010-482). Dallas: Paper presented at the Annual Meeting of the Association for Educational Communications and Technology, Research and Theory Division, Dallas.

Reed, D.D. (1983). Information paper on computer-assisted instruction in higher education and industry (a literature search). Unpublished paper, Air University, Maxwell Air Force Base, AL.

Reeves, T.C., & Lent, R.M. (1982). Levels of evaluation for computer-based instruction. Paper presented at the Annual Meeting of the American Educational Research Association, New York.

Reigeluth, C.M., & Garfield, J.M. (1984). Using videodiscs in instruction: Realizing their potential through instructional design. Using Videodiscs in Instruction, 4(3), 199-214.

Reinking, D. (1983). Unpublished doctoral dissertation, Minneapolis, University of Minnesota.

Reinking, D. (1985, March). On conceptualizing research methodologies for computer-based instruction. Proceedings of the Twenty Sixth International Association for the Development of Computer-Based Instructional Systems (pp. 241-245). Bellingham: Western Washington University.

Robinson, E.R.N., & Kirk, F.G. (1984) Interfacing learning strategies and instructional strategies in computer training programs. In F.A. Muckler (Ed.), Human Factors Review 1984 (pp. 209-238). Santa Monica: Human Factors Society.

Ross, S.M. (1984). Matching the lesson to the student: Alternative adaptive designs for individualized learning systems. Journal of Computer-Based Instruction, 11, 42-48.

Rupp, B.A. (1981). Visual display standards: A review of issues. Proceedings of the SID, 22(1), 63-72.

Salomon, G. (1979). Interaction of media, cognition and learning. San Francisco: Jossey-Bass.

Salomon, G. & Gardner, H. (1986). The computer as educator: Lessons from television research. Educational Researcher, 15, 13-19.

Sawyer, T.A. (1985). Human factors consideration in computer-assisted instruction. Journal of Computer-based Instruction, 12(1), 17-20.

Schubert, J.G. (1985, April). Cooperative learning, equity, and computer learning. Paper presented at the Annual Meeting of the American Educational Research Association, Chicago.

Seidel, R.J. (1980). It's 1980: Do you know where your computer is? (Document No. IR-008-536). Alexandria, VA: Human Resources Research Organization. (ERIC Document Reproduction Service NO. ED 190 059)

Shavelson, R.J., Winkler, J.D., Stasz, C., Feibel, W., Robyn, A.E., & Shea, S. (1984, March). Teaching mathematics and science: Patterns of microcomputer use. Santa Monica: Rand Corporation.

Shlechter, T.M. (1985, November). CBI and students' attitudes. Paper presented at the Annual Meeting of the Mid-South Educational Research Association, Biloxi, MS.

Simonson, M.R. (1980). Instructional media, attitude formation and change. Paper presented at the Annual Meeting of the Association for Educational Communication and Technology, Denver.

Snow, R.E. (1980). Aptitude, learner control and adaptive instruction. Educational Psychologists, 15(3), 151-158.

Steinberg, E.R. (1977). Review of student control in computer-assisted instruction. Journal of Computer-Based Instruction, 3(3), 84-90.

Steinberg, E.R., (1984). Teaching computers to teach (pp. 1-14). Hillsdale, NJ: Lawrence Erlbaum Associates.

Stone, C.S. (1985, March). Instruction at the US Army Engineer School: Evolution and management of an in-house coding team. Paper presented at the International Meeting of the Association for the Development of Computer-Based Instructional Systems, Philadelphia.

Sullivan, BG. G. (1985, May). Computer-Based training at the US Army Armor School. Paper presented at the Annual Meeting of the US Armor Conference. Fort Knox, KY.

Suppes, P., & Morningstar, M. (1969, October). Computer-assisted instruction: Two computer-assisted instruction programs are evaluated. Science, 166, 343-350.

Swezey, R.W., Criswell, E.L., Huggins, R.S., Hays, R.T. & Allen, J.A. (in prep.). Training effects of hands-on practice and three instructional methods on a simple procedural task (ARI-Technical Report). Alexandria, VA: Army Research Institute.

Swezey, R.W., Huggins, R.S., & Perez, R.S. (in prep.). Effects of three instructional delivery methods and hands-on practice on a procedural maintenance task (ARI-Technical Report). Alexandria, VA: Army Research Institute Technical report.

Tatsuoka, K.K., & Misselt, A.L. (1978). Attitude and performance of military students and instructor attitudes in computer-based technical training (Contract No. DAHC 15-73-C-0077). Urbana: University of Illinois, Computer-Based Research Laboratory.

Teaching/Learning Technologies (1984). Introducing . . . the educational computer-in-a-notebook (Brochure). Downers Grove, IL: Nuvatec, INC., Teaching Learning Technologies Division.

Tennyson, R.D. & Buttrey, T. (1980, Fall). Advisement and management strategies as design variables in computer-assisted instruction. Educational Communication & Technology. 28(3), 169-176.

Tennyson, R.D., Christiansen, D.L., & Park, S.I. (1984). The Minnesota Adaptive Instructional System: An intelligent CBI system. Journal of Computer-Based Instruction. 11, 2-13.

Walker, D.F. (1984). Computers in schools, I: Potential and limitations, II: The software problem (Document No. IR 011 114). San Francisco: Far West Laboratory for Educational Research and Development. (ERIC Document Reproduction Service No. ED 244 593).

Williges, R.C., Williges, B.H., & Elkerton, J. (in press). Software interface design. In G. Salverdy (Eds.). Handbook of Human Factors: Ergonomics. New York: Wiley Interscience.

Witkin, H.A., Goodenough, D.R., & Karp, S.A. (1967). Stability of cognitive style from childhood to young adulthood. Journal of Personality and Social Psychology. 7, 291-300.

Witkin, H.A., Moore, C.A., Goodenough, D.R., & Cox, P.W. (1977). Field-dependent and field-independent cognitive styles and their educational implications. Review of Educational Research, 47(1), 1-64.

Wilson, L.S. (1984). Presenting TICCIT: State of the art computer-based instruction. Training Technology Journal, 1(2), 26-32.

Wisher, R.A., & O'Hara, J.W. (1981, May). Computer-based approach to the Navy's Remedial Training Project (PREST): A cost-effectiveness evaluation (NPRDC Special Report 81-18). San Diego, Navy Personnel Research and Development Center.

Wood, J.A., & Pitz, G.F. (1985, October). Computer aversion as source of bias in computerized testing. Paper presented at the Annual Meeting of the Military Testing Association, San Diego.

Zemke, R. (1984, May). Evaluating computer-assisted instruction: the good, the bad and the why. Training Technology Journal, 22-47.